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THE UNIVERSITY OF ALBERTA

MODELLING THE THERMAL ENVIRONMENT WITHIN TOTAL CONFINEMENT LIVESTOCK HOUSING

by

Ⓒ PAUL JOHN BARLOTT

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
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EDMONTON, ALBERTA
FALL, 1974

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Modelling the Thermal Environment Within Total Confinement Livestock Housing", submitted by Paul John Barlott in partial fulfilment of the requirements for the degree of Master of Science.

J.B. McQuitty

Supervisor

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Date 8th July, 1974.

ABSTRACT

A digital computer program for modelling the dynamic thermal characteristics of confinement livestock housing was developed to facilitate the simulation of the thermal environment within such a unit. The mathematical model employs z-transfer functions for the calculation of transient heat transfer through the structural components and accounts for solar radiation heat load as well as the heat produced by the animals. The model predicts the interior temperatures and humidities as well as the interior and exterior surface temperatures as a function of external environment, type of construction and management practices.

The algorithms included in the model give the accuracy and sophistication required to simulate the dynamic thermal environment that exists in commercial livestock housing. A comprehensive documentation of the computer program was prepared to allow use of the model with no serious difficulties. This documentation consists of a detailed explanation of the program via a flow diagram and a detailed explanation of the input and output formats.

The reliability of the predictions made by the model were evaluated by a verification trial in a typical commercial total confinement unit. Specific measurements were made and the recorded data compared with the predicted values that were generated by the model. This validation trial indicated that the prediction of the thermal environment within total confinement livestock housing was accurate, but dependent on the accuracy of the input data.

The potential value of the model for practical and research purposes are discussed. Experience with and modifications to the model are required to define and evaluate any imperfections and limitations that may exist within the model.

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TABLE OF CONTENTS

Page

LIST OF FIGURES x

LIST OF TABLES xii

1. INTRODUCTION AND OBJECTIVES. 1

2. LITERATURE REVIEW. 3

2.1 Livestock and the Environment 3

2.1.1 Social Environment 3

2.1.2 Climatic Environment 4

2.1.2.1 Thermal Environment 4

2.1.2.2 Chemical Environment 5

2.1.3 Structural Environment 6

2.2 Heat and Moisture Production Within Total Confinement 7

2.3 Systems Analysis 10

2.3.1 Systems Concept 10

2.3.2 Modelling and Simulation 11

2.3.3 Applications 12

3. MODELLING PROCEDURE. 15

3.1 Solar Parameters 17

3.2 Z-transfer Function Coefficients 19

3.3 Attic Space Thermal Resistance 20

3.4 Surface Temperatures and Heat Fluxes 21

3.5 Resultant Heat and Moisture Load 22

3.6 Psychrometrics and Ventilation Rate 24

3.7 Inside Dry-Bulb Temperatures 24

4. ASSUMPTIONS. 27

5. PROGRAM DATA. 29
  5.1 Input Data 29
  5.2 Output Data 29
    5.2.1 Numerical Component Data 30
    5.2.2 Solar Parameters and Thermal Properties 30
    5.2.3 Heat Transfer 31
    5.2.4 Ventilation Criteria 32
6. VALIDATION OF THE MODEL. 33
  6.1 The Total Confinement Unit 33
  6.2 Model Parameters 35
    6.2.1 Ventilation Rate 35
    6.2.2 Temperature and Relative Humidity 38
      6.2.2.1 Inside Room Temperature and Relative Humidity 40
      6.2.2.2 Outside and Attic Temperature and Relative Humidity 44
      6.2.2.3 Surface Temperature 47
    6.2.3 Other Weather Data 47
    6.2.4 Heat and Moisture Production 48
    6.2.5 Physical Data of Structural Components 50
    6.2.6 Other Parameters 51
  6.3 The Computer Simulation 55
7. DISCUSSION OF THE VALIDATION RESULTS. 57
  7.1 Initial Validation 57
    7.1.1 Numerical Component Data 58
    7.1.2 Solar Parameters 58

7.1.3 Thermal Properties 61

7.1.3.1 Inside Room Dry-Bulb Temperature 62

7.1.3.2 Inside Room Relative Humidity 64

7.1.3.3 Inside Surface Temperature 66

7.1.3.4 Outside Surface Temperature 72

7.1.3.5 Summary 81

7.1.4 Heat Transfer 83

7.1.5 Ventilation Criteria 84

7.2 Sensitivity Analysis 85

7.2.1 Incoming Temperature 85

7.2.2 Heat and Moisture Production 88

7.2.3 Other Parameters 95

8. SUMMARY AND CONCLUSIONS. 98

9. SUGGESTIONS AND PRACTICAL IMPLICATIONS. 100

10. LITERATURE CITED. 104

11. APPENDICES. 112

Appendix A: PROGRAM FLOW DIAGRAM 113

Appendix B: SOURCE PROGRAM LISTING 191

Appendix C: PROGRAM VARIABLE NAMES AND UNITS 234

Appendix D: INPUT DATA FORMAT 253

Appendix E: INPUT DATA SPECIFICATION 258

Appendix F: TIME REPRESENTATION 263

Appendix G: DATA 265

Appendix H: PROCEDURES 288

Appendix I: VALIDATION INPUT FORMAT 290

Appendix J: VALIDATION OUTPUT 292

Appendix K: COMPUTER TIME AND COST 341

LIST OF FIGURES

FIGURE	TITLE	PAGE
1.	Simplified flow diagram of the model.	16
2.	Definition of angles.	18
3.	Outside view of experimental confinement unit.	34
4.	Inside view of experimental confinement unit.	34
5.	South gable end of experimental confinement unit.	36
6.	Discharge ducts.	36
7.	Velocity probe located in discharge duct.	37
8.	Velocity meter used to measure air flow.	37
9.	Temperature recorder.	39
10.	Thermocouple pair used to measure wet-bulb and dry-bulb temperatures.	39
11.	Floor plan of experimental confinement unit.	42
12.	Experimental inside room dry-bulb temperature.	43
13.	Outside thermocouples located in white shelter.	45
14.	Thermocouple taped to wall surface.	45
15.	Attic and outside dry-bulb temperatures.	45
16.	Attic and outside relative humidities.	46
17.	Service recorder mounted on heater unit.	49
18.	Pyrheliometer to measure the direct normal radiation. . .	54
19.	Pyrheliometer to measure the radiation on a horizontal plane.	54
20.	Inside room dry-bulb temperatures.	63
21.	Inside room relative humidities.	65
22.	South wall inside surface temperatures.	67
23.	North wall inside surface temperatures.	68
24.	East wall inside surface temperatures.	69

25. West wall inside surface temperatures 70
26. Ceiling inside surface temperatures. 71
27. South wall outside surface temperatures. 74
28. North wall outside surface temperatures. 75
29. East wall outside surface temperatures. 76
30. West wall outside surface temperatures. 77
31. West slope outside roof surface temperatures. 78
32. East slope outside roof surface temperatures. 79
33. The effect on inside room dry-bulb temperatures of changing the ingoing air temperatures from that of the outside air to that of the attic space. 87
34. The effect on inside room dry-bulb temperatures of varying the management factor for sensible heat production and maintaining the management factor for moisture production at 0.80. 91
35. The effect on inside room dry-bulb temperatures of varying the management factor for sensible heat production and maintaining the management factor for moisture production at 1.00. 92
36. The effect on inside room dry-bulb temperatures of varying the management factor for sensible heat production and maintaining the management factor for moisture production at 1.20. 93

LIST OF TABLES

TABLE	TITLE	PAGE
1.	STATISTICAL ANALYSIS OF INSIDE SURFACE TEMPERATURES. . .	73
2.	STATISTICAL ANALYSIS OF OUTSIDE SURFACE TEMPERATURES. .	80
3.	STATISTICAL ANALYSIS OF INSIDE DRY-BULB TEMPERATURE RESULTING FROM SENSITIVITY ANALYSIS ON HEAT AND MOISTURE PRODUCTION.	94

1. INTRODUCTION AND OBJECTIVES

The need for sophisticated environmental modification has increased as livestock producers raise more animals in high density total confinement houses. These modifications play a significant role in determining whether the producer realizes a profit or loss.

The traditional practice for design of livestock structures has involved assigning desired interior conditions, selecting a mean outside design condition and applying steady state heat and mass transfer relationships to establish the design. This approach for design of total confinement is limited by certain factors such as the moderating influence exerted by thermal capacities of the structural components, the variation of animal heat production with changes in temperature and other ambient conditions, and with the influence of solar heat load on the structure.

In the past decade, many techniques of systems analysis, including mathematical modelling and computer simulation have been applied to the analysis and solution of many agricultural problems. A digital model was developed to determine the dynamic thermal characteristics of a hypothetical swine barn by Feddes et al (39). This model applied modern mathematical algorithms to the transient heat transfer through walls and roof and was able to account for the effect of solar heat load as well as the heat produced by the animal.

The objective of this research project was to develop a model of the thermal environment within total confinement livestock housing, which could be utilized for systems analysis of environmental control alternatives. To help achieve this objective would necessitate:

1. Modification of the existing mathematical model (39) to achieve the accuracy, flexibility and adaptability necessary for systems analysis of environmental control. The model would require altering to permit prediction of interior temperatures and humidities as well as interior and exterior surface temperatures as a function of external environment, type of construction, and management practices.
2. Preparation of comprehensive documentation of the computer program. This would require detailed program flow charting and input/output formats.
3. Verification of the model with a typical commercial total confinement unit. This would include collection of specific measurements and comparison of these with predicted values generated by the model.

2. LITERATURE REVIEW

2.1 Livestock and the Environment.

In biological terms, environment may be defined as "all the conditions, circumstances, and influences surrounding, and affecting the development of, an organism" (45). An animal's environment consists of all external conditions that affect its development, growth and response. Baxter (9) suggests that the environmental complex should be considered from the aspects of three primary constituents - social, climatic and structural. The social and structural environment will be discussed only briefly since the climatic environment is of major concern in this model.

2.1.1 Social Environment.

Scott, as cited by Baxter (9), divided the general behavioral functions of animals into nine categories and indicated the building design considerations for each. These categories considered the following: food receptacles should be properly sized, shaped and located; properly designed defecating and urinating areas should be provided; convenient mating areas should be designed; good design should eliminate danger zones for inquisitive young stock, yet allow freedom for mother/young relationships; and, proper design and layout should be considered to maintain dominance/subordination relationships when livestock are kept in groups.

Baxter (9) noted that the area of the stock confinement and the number of livestock on such an area combine to produce a given stocking density but, although the stocking density may be constant for any number of animals, the group behavior and performance may be affected by the actual numbers of individuals within the group. The number of animals also may be selected on the basis of reducing the amount of supplemental heat required (36). Stocking density must be selected such that moisture produced within the building can be removed in the winter and excess heat removed in the summer by means of the air exchange system.

2.1.2 Climatic Environment.

The weather of any region may vary with a fairly wide range of climatic variations. With the introduction of technology, some degree of control over the climatic factors is now feasible by providing total confinement environments.

The climatic environment may be subdivided into the thermal environment and the chemical environment (9). The thermal environment consists of the dry-bulb temperature, air movement, air moisture content and mean radiant temperature, while the chemical environment consists of vapors, gases, dusts and odors.

2.1.2.1 Thermal Environment.

Several references have summarized the thermal environmental requirements of livestock and poultry (2,4,8,9,36,104). These sources note the need to avoid low temperatures because of the extra energy expended for body temperature maintenance.

The level of the ambient temperature is generally accepted as the environmental factor that most affects the performance of growing-finishing swine (4,17,36,44,51,52,53,71,80). Various research results are not in complete agreement as to the magnitude of the differences in performance that occur at various air temperatures, but temperatures of approximately 74°F for lightweight pigs and 62°F for heavyweight hogs are generally found as the environmental temperature at which swine achieve maximum growth patterns. Bond et al (17) found that, if daily air temperatures cycle more than 10^{o}F on either side of 70^{o}F, the daily gain of pigs will be lowered and their feed requirements per pound of gain will be increased. In agreement, Harman et al (50) found that small diurnal variations in air temperature (60^{o}F - 70^{o}F) do not greatly reduce the production efficiency of swine. However, separate environments in a farrowing house are a major problem, for the optimum temperature at which pigs appear to thrive is too high for a sow.

Maximum efficiency in egg production is achieved in an environment which provides ambient temperatures in the 55 - 60^{o}F thermoneutral range according to Phillip and Esmay (85) while Yeck (107) defines this range as being between 45^{o}F and 65^{o}F. Others (33,65) found that higher temperatures of around 75^{o}F are the environmental conditions under which the least feed is consumed.

The optimum temperature range for beef and dairy cattle is large and dependent on breed, age, weight and condition of the animal (36,61). The range within which dairy cattle will maintain a normal level of milk production is usually given as 10^{o}F to 80^{o}F while that for normal gains in beef cattle is given as 0^{o}F to 80^{o}F (2,4,8,36).

Water has been shown to relieve heat stress of pigs under a variety of conditions (18,29,48,54,78). In these investigations, spraying periodically and allowing the pig to dry between wettings was found to have an advantage over other methods.

2.1.2.2 Chemical Environment.

In general, the chemical constituents of the climatic environment result from the processes which occur within total confinement livestock production units. Only since rapid changes have been occurring in housing and husbandry systems, has attention been given to the chemical aspects of the climatic environment.

Baxter (9) stated that the majority of odors emanating from livestock production enterprises are associated with the biological degradation of the animal wastes and the body odor of the animals. Dale and Ogilvie as cited by Hoglund and Albright (56) suggest that operators must be made aware of the possible side effects of such gases as hydrogen sulfide, ammonia, carbon dioxide and methane on livestock and man if proper precautions are not taken. Gases and objectionable odors must be removed from confinement housing; however, it appears that if the ventilation system removes the vaporized moisture, the other ventilation requirements will be satisfied (36,50).

With the advent of stronger pollution control regulations, the type of waste management system to use becomes a major decision in livestock confinement housing. A very detailed annotative bibliography of research in the waste management area (72) defines this area very well. Public attitudes toward manure odors and pollution of streams, rivers and lakes must be considered in the location of new livestock units and the type and structure of waste management selected.

2.1.3 Structural Environment.

Baxter (9) states that the structural environment may be created by natural or manufactured objects. With increased emphasis on intensified livestock production in total confinement, the structural environment is becoming more man-made. The same author also states that the type of floor, its age, surface texture and condition, materials and construction, may all lead to animal discomfort, injury or even disease. Discomfort and injury to livestock can also result from poorly designed equipment, and poor overall planning.

2.2 Heat and Moisture Production Within Total Confinement.

Livestock and poultry produce various quantities of heat and moisture. For the design and operation of any effective environmental control system, the quantities of heat and water vapor produced in the building must be predicted accurately. This means that the use of bedding, arrangement of the gutters, the method of barn cleaning, and the type of waterers used, certainly will affect the amount of free water evaporated, as well as the amount of sensible heat left for heating the building.

Dick and Loader (32) state that heat loss in the form of water vapor may vary considerably depending upon management practices, building design, and effectiveness of the ventilation system. Many results of investigations in the areas of heat and moisture production have been summarized and presented as recommended values for moisture and heat production for cattle, pigs and poultry in codes and standards for ventilation design purposes (2,4,8). There are limitations to these criteria as they are too generalized to meet all situations where a number of factors react differently than those on which the data are based.

Reece and Deaton (87) found that the total heat removed from a poultry unit during the summer was the same as the total heat removed during the winter with the only difference being the sensible to latent heat ratio. This ratio of sensible to latent heat production may be affected by age, weight, conditions and species, by ambient and mean radiant temperatures and by plane of nutrition of the animals confined (36).

Reece and Deaton (87) suggested that sensible heat production was not satisfactory as a ventilation criterion because of the occurrence of low sensible heat removal during the afternoon which may have been due to:

1. a reduction in heat production of the animals since there was less activity and an adjustment in metabolism at this time,
2. floor litter becoming , in fact, a heat sink at high temperatures with the release of heat as ambient temperatures fall as a result of decreasing outside temperatures, or
3. the sensible heat being used to evaporate litter moisture during the afternoon when the lowest relative humidity existed.

The proportion of metabolic heat dissipated by evaporation increases with rising environmental temperatures and with decreasing temperature gradient between the animal and air. The amount of moisture removed from a confinement unit approaches the total water consumed as ambient temperature increases (15). Esmay et al (37) found that high outside temperature conditions appeared to bring about higher ratios of latent heat removal even when high outside relative humidities prevailed than at lower outside temperature. Mount (80) found that, as a proportion of total heat loss, the evaporative heat loss of pigs rose from 8% at $48^{\circ}F$ to 10 - 20% at $86^{\circ}F$ and then to 30 - 60% at temperatures above the critical level of $93^{\circ}F$. Butchbaker and Shanklin (20) obtained similar values from their measurements. Further research by Morrison et al (77) indicated that the physical environmental factors cannot account directly for the change or lack of change in the rate of vapor production of swine under different conditions.

Bond et al (14) studied the effect of wind on swine production and found sizeable increases in total heat loss due to wind even at ambient temperatures as high as 90°F. Total heat loss increased with increased wind in spite of reduced radiation losses. As indicated in this study, air velocity should be considered in estimating heat loss quantities.

Air-conditioning and ventilation for hog houses requires accurate information on optimum productive environments for hogs and the heat and moisture they produce. Bond et al (16) presented heat and moisture relationships needed for designing hog house ventilation, insulation or air conditioning for optimum environmental conditions for hogs 50 to 400 pounds at air temperatures of 40°F to 100°F. Changes in heat and moisture content of the air passing through the room were used as a measure of heat and moisture released by the animals. Animal management and conditions within the test chamber were representative of normal farm conditions. No bedding was used and the pens were cleaned twice daily. Air velocities were usually from 15 to 30 feet per minute accounting for 20 air changes per hour and the relative humidity was near 50%.

Harmon et al (50) compared the quantity of moisture removal by ventilation air from swine pens with a slatted floor, a partially slatted floor and a concrete floor. They found highly significant differences between moisture vapor removal rates of the three pens.

They concluded that water vapor produced by swine in a slatted floor house that must be removed by ventilation (lagoon underneath) is 0.42 as much as that in a concrete floored house. For a partially slatted floor, the removal is directly proportional to the percentage of the floor that is slatted. They also found that the regression equations of Bond et al (16) were useful for prediction of heat and moisture production, but must be adjusted for slatted floors. Also, if bedding is used on solid floors, the data can increase by as much as one-third. For beef housing, Feddes and McQuitty (38) found the water vapor produced by beef in a slatted-floor house that must be removed by ventilation is 0.69 as much as that in a straw-bedded solid-floor house.

For design purposes, the regression equations and data (16) for heat and moisture production reflect the actual conditions better than many other methods used for these calculations (2,4,23). This data is true only for air velocities not exceeding 50 fpm and must be adjusted where slatted floors are used. There also are many other influencing factors such as relative humidity, feed ration, etc. not included in the regression equation. This would suggest that there is no precise prediction method currently available.

2.3 Systems Analysis.

2.3.1 Systems Concept.

In a society that is producing more people, more materials, and more information than ever before, the systems approach is indispensable in meeting the challenges of the complexity of interrelationships that exist in modern systems. For example, in a study into food production by Rodda (89), no less than eighteen universities cooperated to give the participants experience in the systems approach.

The systems method recognizes each system as an integrated whole even though composed of diverse, specialized structures and subfunctions (24,25). Systems analysis emphasizes the total process, rather than the individual sectors of the process (34).

Operations Research in many cases is referred to as being synonymous to systems analysis. Wagner (101) defines operations research as a scientific approach to problem solving involving the construction of mathematical, economic, and statistical descriptions on models of decision and control problems to treat situations of complexity. Systems analysis is the selection of elements, relationships, and procedures to achieve a specific purpose (100).

Systems analysis techniques presently are being utilized in many areas of research and management. Preston (86) presents a good guide to some of the sources of applications of systems analysis methods. Presently, computers are being used in many of these applications (26). Since Charles Babbage's Analytical Engine of about 1840 (43), computer technology has advanced to where it is absolutely essential to analysis and understanding of complex phenomena.

2.3.2 Modelling and Simulation.

In systems analysis, a model is usually a mathematical and necessarily an approximate representation of reality. With parameters specified by historical and technological data, mathematical solutions then can be calculated. The model also must be validated. Sensitivity testing is an essential part of the validation process.

In the design of a system, the development of a simulation model that is sufficiently general to be adaptable to many and varied situations is desirable. According to McLeod, as cited by the Department of Chemical and Petroleum Engineering (30), "simulation is the act of representing some aspects of the real world by numbers or symbols which may be easily manipulated to facilitate their study..." By the process of representing through analogy, simulation has been developed as a powerful analytical tool in the solution of numerous problems (66). Simulation and the use of the computer have become very closely linked merely because of the large number of calculations required in even the simplest of simulation models. The crux of the problem, of course, is intimate man-machine communication. "... The engineer requires a conveniently manageable system, the scientist requires sufficient intimacy to provide real insight into the complex interplay of problem variables; the creative user requires computing power and flexibility to permit imaginative use of the computer and graphic display to permit recognition of inventive solutions..." (30).

Wagner (101) states that model-building is the essence of the operations research approach. Such a model assists in putting the complexities and possible uncertainties attending a decision-making problem into a logical framework amenable to comprehensive analysis. A model is then a vehicle for arriving at a well-structured view of reality.

2.3.3 Applications.

Systems analysis techniques have been suggested and applied to many agricultural situations and problems (5,6,22,63,67,68,90). The tools of the systems approach are usually models and, more recently, computer-based models to speed the process of modelling.

Many models have been developed to assist in systems analysis of environmental control. Albright and Scott (1) presented a mathematical analytical solution which predicted the inside temperature of a ventilated structure subjected to daily variations of outside air temperature and solar heating. Beckett and Vidrine (11) presented a mathematical model that predicted the effects of thermal environment on some physiological responses of a pig, including heat produced, moisture produced, pig surface temperature and the weight gain. A general model of air-conditioning calculations was developed by Mitalis et al (76), while Phillips and Esmay (85) developed a model of the environmental surroundings of the laying hen and adapted this model for computer simulation studies. Paine and Nelson (84) discussed an analog simulation model for a system control engineering approach to prediction of animal growth/environment interaction. Carson (23) presented a digital model for swine environments predicting the gain and feed conversion fractions calculated using mean values of simulated ambient temperatures and relative humidities.

The main short-coming of many of these models is that they have been developed for a specific situation and require major revisions before they may be applied to the prediction of the environment in total confinement resulting from a wide range of design and management factors. Only after models have been developed that incorporate the sophistication necessary for systems analysis can they be integrated into an overall agricultural model and applied in the process of farm rationalization.

The Feddes et al model (39) determined the thermal characteristics of a total confinement livestock unit for a wide range of design and management factors, offering a level of sophistication that was not previously available. As indicated by the reference source, experience and modification are required to fully evaluate the limitations of the model. However, improving upon the accuracy, flexibility and adaptability of the model may lead to a better understanding of the dynamic thermal environment within total confinement livestock housing.

3. MODELLING PROCEDURE

Model formulation is an inductive process in which the mathematical relationships between variables are hypothesized to describe the system to be studied.

The revised model of the thermal environment in total confinement swine housing (referred to as "the model" throughout the remaining discussion) is represented in the flow diagram (Figure 1). The model is divided into seven basic parts to provide the following functions:

1. Determination of solar position, intensity of solar radiation on outer surfaces of the total confinement unit, sol-air temperature, and solar heat gain factors for the building.
2. Calculation of the z-transfer function coefficients for walls, roof and doors.
3. Calculation of the thermal resistance of the attic space in the pitched roof.
4. Calculation of surface temperatures and heat fluxes for the individual structural components of the unit.
5. Calculation of the resultant heat load and moisture load for the unit.
6. Determination of ventilation rates at hourly intervals based on psychrometric and physiological data.
7. Determination of the inside dry-bulb temperature for the confinement unit.

Each of these sections is described briefly to generally describe the very detailed flow chart (Appendix A) which contains all the

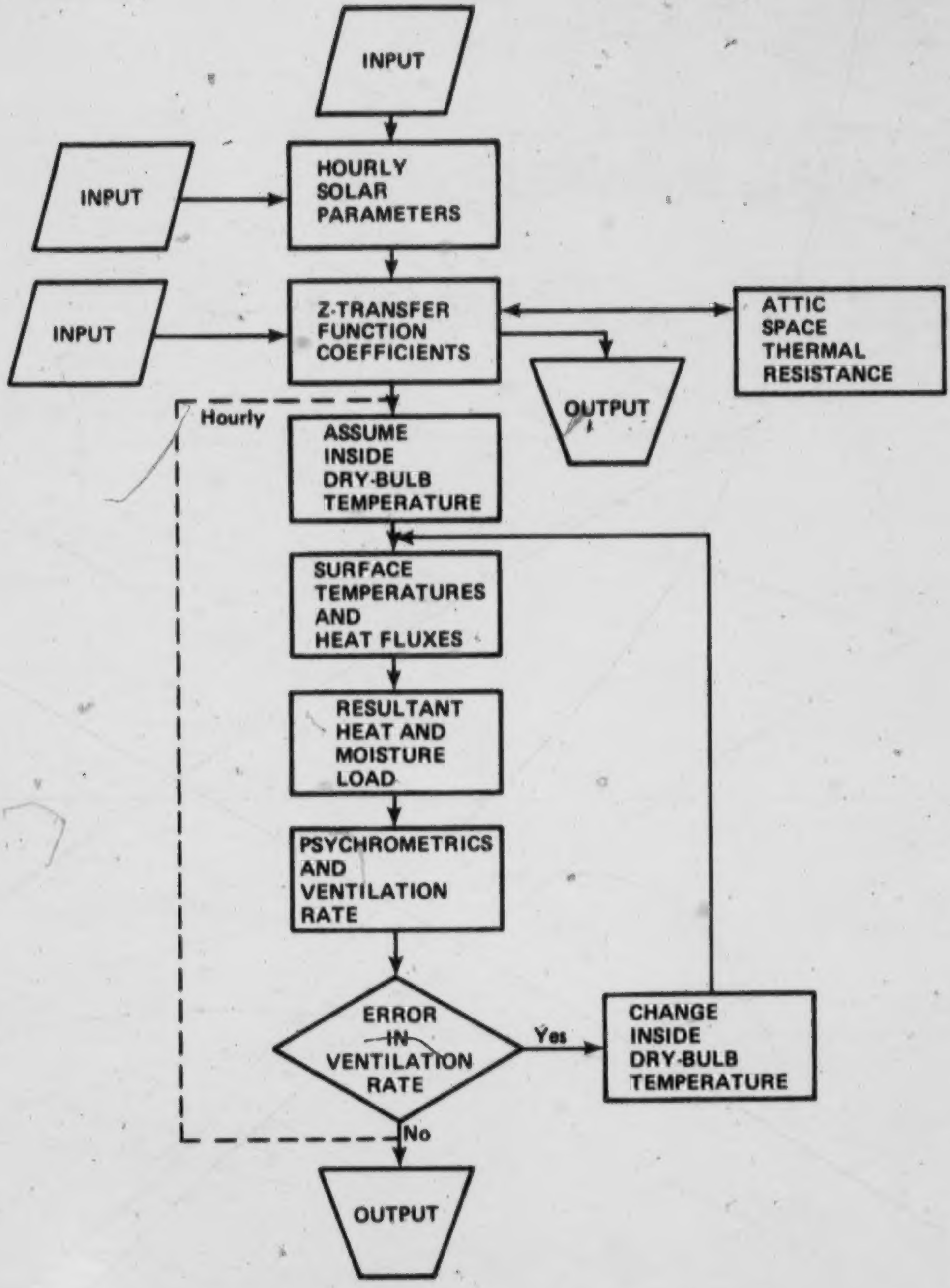
INPUT
INPUT
HOURLY SOLAR PARAMETERS
INPUT
Z-TRANSFER FUNCTION COEFFICIENTS
ATTIC SPACE THERMAL RESISTANCE
OUTPUT
Hourly
ASSUME INSIDE DRY-BULB TEMPERATURE
SURFACE TEMPERATURES AND HEAT FLUXES
RESULTANT HEAT AND MOISTURE LOAD
PSYCHROMETRICS AND VENTILATION RATE
ERROR IN VENTILATION RATE
Yes
CHANGE INSIDE DRY-BULB TEMPERATURE
No
OUTPUT

Figure 1: Simplified flow diagram of the model.

mathematical relationships and algorithms used. The source program, presented in Appendix B with a definition of the variable names in Appendix C, is coded in Fortran IV for computer simulation.

3.1 Solar Parameters.

Solar simulation should be considered in building environmental systems design although in some cases it may be an insignificant factor (103). Kimura and Stephenson (62) state that solar radiation is one of the most important components of the heat balance at the outside surfaces of buildings, and that solar heat which enters a building through the windows is a major element in the total heat gain by the building. Höglund et al (57) found that a simple method of using average inside-to-outside air temperature difference to calculate daily average heat flow gives very large errors because solar radiation is neglected entirely.

Several algorithms (3,4,93,99) are combined and included in the model to determine the solar position, the intensity of the solar radiation incident on the outer surfaces of the building, the sol-air temperature for the surfaces, and the solar heat gain factors for heat gain through the windows of each surface. These calculations are carried out within subroutine SOLAR (Appendix A and B) and give the accuracy necessary for the solar effects on the environmental system (91,93). The definition of the angles that are presented in this subroutine are illustrated in Figure 2 (3).

The mathematical relationships used in SOLAR calculations are common expressions except for some of the special calculations. The variables related to solar radiation including declination angle, equation of time, apparent solar constant, atmospheric extinction

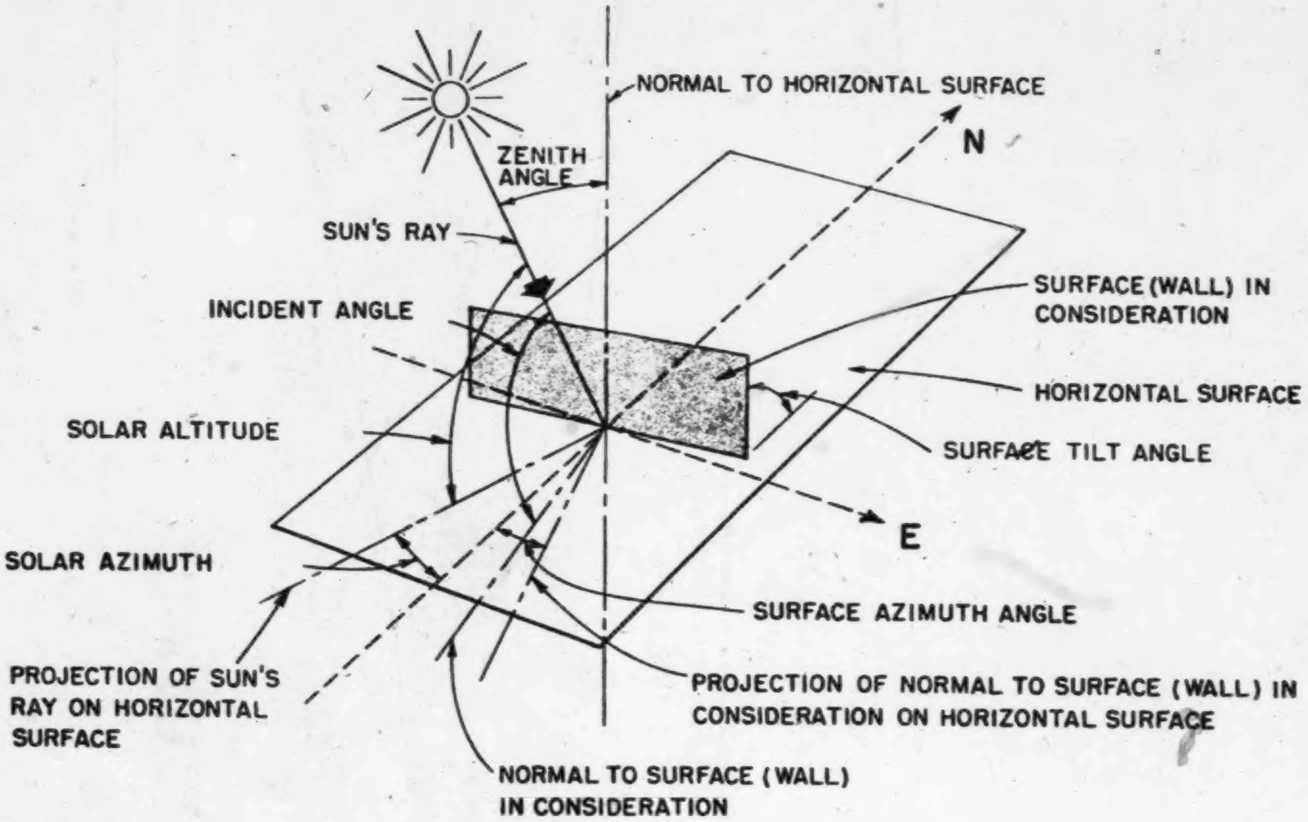
NORMAL TO HORIZONTAL SURFACE
N
ZENITH ANGLE
SUN'S RAY
SURFACE (WALL) IN CONSIDERATION
INCIDENT ANGLE
HORIZONTAL SURFACE
SOLAR ALTITUDE
SURFACE TILT ANGLE
E
SOLAR AZIMUTH
SURFACE AZIMUTH ANGLE
PROJECTION OF SUN'S RAY ON HORIZONTAL SURFACE
PROJECTION OF NORMAL TO SURFACE (WALL) IN CONSIDERATION ON HORIZONTAL SURFACE
NORMAL TO SURFACE (WALL) IN CONSIDERATION

Figure 2: Definition of angles (3).

coefficient and sky diffuse factor are expressed in a truncated Fourier series form to avoid interpolation procedures and to save computer core space (3). The equations for calculation of the cloud cover modifier for each combination of cloud type, total cloud amount, and solar altitude angle are expressed as a cubic relationship (3). The transmission and absorption factors for windows are expressed as polynomials developed by the Division of Building Research, National Research Council, as cited by several sources (3,4,93).

3.2 Z-transfer Function Coefficients.

Only until recently, the design of environmentally controlled agricultural buildings for production of livestock and poultry, and the storage of fruits and vegetables has been based largely on the assumption of steady-state heat transfer. To predict the dynamic thermal environment within total confinement, the analysis of the system dictates design based on transient conditions since transient heat transfer is the actual mode of heat transfer in most agricultural buildings.

The periodic heat flow in homogeneous and composite walls, as well as the concept of accounting for sol-air temperature, was considered as early as 1944 (69,70). Constant inside and outside temperatures were assumed in these cases. Later,finite differences to model the transient heat transfer through walls, ceilings and floor were considered (103).

Jordan and Barwick (58) developed an analog computer solution for transient heat transfer through composite walls. At approximately this same time, Mitalas and Arseneault (74) developed a computer program to determine the response factors for transient heat transfer in multi-layer slabs as used by Feddes et al (39) and Jordan et al (59).

Recently, Mitalas and Arseneault (75) documented a program used to calculate the z-transfer functions (95) for the calculation of transient heat transfer through walls and roofs. This program, which evaluates the z-transfer functions (pulse transfer functions) that are exact for either a unit step input, a ramp type input or a periodic input with specified harmonic components, is incorporated into the model of the thermal environment within total confinement swine housing.

"The use of z-transfer functions simplifies the calculation of transient heat flow through composite walls and roofs without requiring any assumptions except that the process can be described by linear differential equations." (95) The program developed by Mitalas and Arseneault (75) evaluates the set of Laplace transfer functions that relate temperature and heat flux at any plane in a wall to boundary conditions which may be given in terms of surface temperatures, surface heat fluxes, or temperature at one surface and heat flux at the other. The method requires finding the poles of the Laplace transfer functions and evaluating the residues at the poles for walls made up of any number of layers of homogeneous materials (95).

The algorithms used to calculate the z-transfer function coefficients A_0, A_1, A_2 ..., B_0, B_1, B_2..., C_0, C_1, C_2 ... and D_0, D_1, D_2 are not documented in detail in the flow chart (Appendix A), but are included in the source program listing of subroutines NAMEA1, POLES, MATRIX, ORIGIN, FREQRE, POLYM and SOLVN (Appendix B). A detailed documentation is presented by Mitalas and Arseneault (75).

3.3 Attic Space Thermal Resistance.

The algorithm used to determine the thermal resistance of the attic space in a pitched roof is that described by A.S.H.R.A.E. (3) for computerized calculations. The major assumption made is that the space can be equated to that of a rectangular cavity with a height of one-half the gable height. The calculations include such variables as the thickness of the air space, the direction of the heat flow, the emissivity of the surfaces facing the air cavity and the space temperature.

3.4 Surface Temperatures and Heat Fluxes.

The z-transforms of the heat fluxes at the surfaces for a wall or roof are related to the z-transforms of the outer and inner surface temperatures resulting in the general equations for heat flux at the inner and outer surface of a wall or roof as presented in the flow chart (Appendix A) (3). If the coefficients of heat transfer at the surfaces are known, they can be combined with the wall or roof z-transfer function coefficients to give a set of over-all factors that relate surface fluxes to the outside and inside air temperatures.

Included in the heat balance are the convection and radiation at the outside surface and convection at the inside surface. The heat balance equations (39) then are solved simultaneously in the model using the iterative procedure (73) to solve for the outside and inside surface temperatures.

The detailed mathematical calculations for these procedures are illustrated in subroutines START and FLUX (Appendix A and B). Subroutine START performs the calculations for the first seven hours of simulation when the surface temperature and heat flux history must be estimated prior to computation, while subroutine FLUX performs these calculations for the remaining time when the surface temperatures and heat fluxes are known.

The number of z-transfer function coefficients for a certain slab indicates the time interval in which each surface temperature and heat flux would have an effect on the heat transfer of the slab. This number also indicates the time interval required to start the computations in advance such that the results are independent of the surface temperatures and fluxes which were estimated prior to the computation in the same manner as the response factors do as presented by Stephenson and Mitlas (94).

Hoglund et al (57) conducted a study in which the thermal response factor method of calculating heat fluxes and surface temperatures was found to give values in good agreement with measured values when the sol-air temperature included the effect of long-wave radiation exchange between the roof and sky. As z-transfer functions give results similar to response factors, it may be assumed that accuracy is maintained.

3.5 Resultant Heat and Moisture Load.

In order to establish the heat available to warm the incoming air such that the moisture may be removed and the desired indoor temperature maintained, the total heat and moisture produced within the unit must be determined (2,4,35,36,64).

The heat transfer through the building components, the supplemental heat production of the heater, and the heat production of the animals are the source of heat load, while the moisture production of the animals and surrounding surfaces are the source of moisture. The resultant heat load then is available for heating the exchange air and vaporizing excess moisture within the facility.

The heat transfer through the building components (walls, doors, windows, roofs and floor) is calculated within subroutine WALL while the heat and moisture production of the animals and surrounding wet surfaces is calculated within subroutine HPROD according the regression equations presented by Bond et al (16). A management factor also is incorporated for specification by the user to alter the sensible heat and moisture production of the animal as suggested by several references (2,4,50). Harman et al (50) suggested that the water vapor produced by swine on a slatted floor that must be removed by ventilation (lagoon underneath) is 0.42 that on a concrete floor. One of the major short-comings of these results is that the experimental units were not similar with regard to relative humidity. Furthermore, water vapor produced by swine on a straw-bedded floor may be as much as 1.3 times that on a concrete floor (2,4).

The assumption used for predicting heat and moisture production is considered by the author to be the best that could be made with the data available. This assumption that the regression equations (16) apply for predicting heat and moisture production of swine also was utilized by Carson (23) with a fairly high degree of accuracy. Other models such as that by Beckett and Vidrine (11) could be used, but many of the assumptions do not coincide with reality and are much too detailed and involved for inclusion in this model. The output also includes the heat and moisture losses for one square foot of pig, leaving a large assumption as to the total square footage of pigs confined. Many input parameters such as pig surface temperature and forced convection air velocity also are required, whereas an attempt was made to minimize these parameters and to keep the model as general as possible for ventilation design purposes.

3.6 Psychrometrics and Ventilation Rate.

The psychrometrics are calculated according to several algorithms for inclusion in the model (2,4,99). These calculations are similar to those documented by Feddes et al (39) except for the addition of equations for calculation of the enthalpy of air and the calculation of vapor pressure of air as documented in the detailed flow chart (Appendix A). The calculations for enthalpy are those given by several references (4,60,96,99), whereas the vapor pressure is calculated according to the formulas given by Goff as cited by the American Society of Heating, Refrigerating and Air-conditioning Engineers (4) for vapor pressure over liquid water and over ice.

Subroutine PH2O determines the vapor pressure over liquid water while subroutine PICE determines the vapor pressure over ice (Appendix A and B). All the psychrometrics and the calculations of the ventilation required to remove heat and that to remove moisture are presented in subroutine VENTIL.

3.7 Inside Dry-Bulb Temperatures.

The inside dry-bulb temperatures are predicted by a trial and error procedure. Initially, the temperature is assumed as $65^{\circ}F$ or $5^{\circ}F$ higher than the ingoing dry-bulb temperature, whichever is greater. Given this inside dry-bulb temperature, the model proceeds through all remaining psychrometric calculations. Finally, the calculated ventilation rate required to remove the heat load at this temperature is compared to the ventilation rate within the confinement unit. If the error in ventilation rate calculation is within the allowable error specified by the user, the model proceeds to the next hour.

When the percentage error in ventilation rate calculation is greater than the maximum desired, the temperature is altered and the thermal characteristics recalculated. If the ventilation rate is greater than the existing ventilation rate within the building, the inside dry-bulb temperature is increased; whereas with a calculated ventilation rate less than that existing within the unit, the inside dry-bulb temperature is decreased.

To minimize computer time in the trial-and-error procedure, several algorithms were devised for incrementing temperatures as follows:

1. For incoming air with a relative humidity of less than 50%, the inside dry-bulb temperature is incremented by ± 0.1°F.
2. For inside dry-bulb temperature greater than 75°F, the inside dry-bulb temperature is incremented by ± 0.1°F.

Whenever these two conditions are not met, changes in inside dry-bulb temperature are made according to the percentage error in ventilation rate calculations according to the following algorithms:

1. For error greater than that specified as acceptable and less than 15%, temperature is incremented by ±0.1°F.
2. For error between 15% and 25%, temperature is incremented by ±0.2°F.
3. For error between 25% and 50%, temperature is incremented by ±0.5°F.
4. For error between 50% and 75%, temperature is incremented by ± 1.5°F.
5. For error greater than 75%, temperature is incremented by ± 3.0°F.

As mentioned previously, whenever the calculated ventilation rate required to remove the resultant heat load is within the accuracy specified by the user, the model proceeds to the next simulation hour.

4. ASSUMPTIONS

In order to mathematically describe the complex dynamic interaction of the animal and the environment so that a computer model could be prepared, several assumptions were made. As research continues, some of these assumptions may be replaced by actual data.

The following are the major assumptions made within the model:

1. The air temperature within the confinement unit is the same floor to ceiling, wall to wall and fan inlet to fan outlet.
2. The moisture content within the confinement unit is the same floor to ceiling, wall to wall and fan inlet to fan outlet.
3. There is no heat storage within the equipment and other materials within the confinement unit.
4. Management methods for reducing moisture production and altering sensible heat production are accounted for in a simple management factor for sensible heat production as well as one for moisture production; e.g., slatted floor versus straw-bedding.
5. Sensible heat production of the animal is influenced only by the size of the animal and by the surrounding temperature, otherwise sensible heat is constant.
6. Latent heat production of the animal is influenced only by the size of the animal and by the surrounding temperature, otherwise latent heat is constant.
7. The amount of any additional heat load due to lights, motors, etc. is of minor importance.
8. Heat loss and heat gain due to infiltration are of minor importance.

9. There is no difference in results whether the ventilation system uses either intake or exhaust fans.
10. The wind direction and wind speed has no effect on the building heat exchange or on the effectiveness of the ventilation system.
11. All structural components are dry.

5. PROGRAM DATA

Since the program for the modelling of the thermal environment within total confinement is to be understood by all those wishing to use the model, a detailed explanation of the input and output data format is necessary.

5.1 Input Data.

The input data format, adhering to conventional format for Fortran IV (28), is presented in Appendix D and E. Where certain data are optional these are indicated, whereas those that are necessary are defined clearly.

The data may be entered on cards for batch processing, or entered on line-file and stored on disk-file, drum-file or magnetic tape for both conversational or batch processing. One should note that the maximum simulation period is four days and the units are specified in the "English System" (Appendix E). Also, one should note that where there are less than seven component orientations and less than four different types of component (i.e. wall, pitched roof, horizontal roof and doors), 'dummy' or artificial variables must be inserted. This 'dummy' variable is usually inserted where one type of roof does not exist (either horizontal or pitched) and must be inserted to assure successful computer processing. Eventually this complication may be overcome by altering the computer program.

5.2 Output Data.

The computer output may be divided into four basic sets of information - the component numerical data, solar parameters and thermal properties, heat transfer through the structural components, and the ventilation criteria. These data are printed in the normal digital computer format requiring a minimum character length of 135 symbols or characters.

5.2.1 Numerical Component Data.

The program output gives the numerical data for each component (wall, roof and door) including the layer thickness, feet; layer conductivity, BTU/(hr)(ft)^2(^{o}F) per foot of thickness; layer specific heat, BTU/(lb)(^{o}F); layer density, (lb)/(ft)^3; layer resistance, ^{o}F/(BTU)(hr)(ft^2); and the description of each layer of the component. The overall thermal conductance, BTU/(hr)(ft)^2(^{o}F), of the component is given as well as the sampling time interval and the z-transfer function coefficients calculated for each component.

5.2.2 Solar Parameters and Thermal Properties.

For each component, component orientation and hour of each day, a summary of specific solar parameters and thermal properties are printed. These parameters include:

1. clock time, hours after midnight;
2. solar time, hours from solar noon;
3. solar altitude, degrees above horizontal;
4. solar azimuth, degrees from South;
5. direct normal intensity of solar radiation incident, BTU/(hr)(ft^2);
6. intensity of the direct solar radiation incident on the outer surface, BTU/(hr)(ft^2);
7. total intensity of the solar radiation on the outer surface, BTU/(hr)(ft^2);

8. solar heat gain factor for the windows;
9. sol-air temperature of the outer surface, ^oF;
10. outside dry-bulb temperature, ^oF;
11. outside wet-bulb temperature, ^oF;
12. longwave radiation at the outer surface, BTU/(hr)(ft^2);
13. short wave radiation at the outer surface, BTU/(hr)(ft^2);
14. convection at the outer surface, BTU/(hr)(ft^2);
15. heat flux at the outer surface, BTU/(hr)(ft^2);
16. heat flux at the inner surface, BTU/(hr)(ft^2);
17. convection at the inner surface, BTU/(hr)(ft^2);
18. surface temperature of the inner surface, ^oF;
19. surface temperature of the outer surface, ^oF,; and
20. inside dry-bulb temperature, ^oF.

Where the building component in question is a 'dummy' or an artificial, a tableau is printed giving the output parameters for the artificial component. The insertion of zero for the area of this component prevents the heat transfer through the component from being added to the total heat load within the building. Therefore, the temperature and psychrometric calculations are not affected by this 'dummy' or artificial variable.

5.2.3 Heat Transfer.

The heat flow, BTU/hr, for each hour of the simulation period is printed for the walls, doors, floor, horizontal roof (no attic space), pitched roof and windows as well as the total heat flow through all the building components. Positive values indicate heat flow into the building, while negative values indicate heat flow outward.

5.2.4 Ventilation Criteria.

The following hourly ventilation criteria are printed for the total confinement unit;

1. existing ventilation rate within the confinement unit, cfm;
2. ventilation rate required to remove moisture at relative humidity specified by the user, cfm;
3. relative humidity assumed for optimal moisture removal as specified by the user, percent;
4. ventilation rate required to remove the resultant heat load, cfm;
5. relative humidity at the ventilation rate required to remove the resultant heat load, percent;
6. supplemental heat or refrigeration required to ensure a ventilation rate required to remove moisture, BTU/hr;
7. total sensible heat load within the building, BTU/hr;
8. total sensible heat produced by the animals and the heater, BTU/hr;
9. incoming dry-bulb temperature, °F;
10. inside dry-bulb temperature, °F;
11. incoming wet-bulb temperature, °F;
12. moisture production within the building, lbs/hr; and
13. relative humidity of the incoming air, percent.

6. VALIDATION OF THE MODEL

In the course of simulation, confirmation of the model through appropriate comparisons with experimentally derived data is essential to predict the reliability and accuracy of the model in predicting the dynamic thermal characteristics within total confinement.

6.1 The Total Confinement Unit.

The total confinement unit (Figure 3 and Figure 4) used for the verification of the model was chosen on the basis of a unit that would represent a typical commercial farm operation. The Swine Finishing Barn located at the University of Alberta, Faculty of Agriculture and Forestry Edmonton Research Station, Edmonton, Alberta, was used to represent the typical swine unit. This facility was constructed in the early 1950's by a local pre-fabrication company for research activities of the Department of Animal Science.

The building was 68 feet 2 inches long by 36 feet 8 inches wide by 6 feet 4 inches to the eaves and orientated with its long axis running north-south. The frame walls of the structure consisted of 0.032 inch aluminum exterior siding and two 3/8-inch plywood sheathing skins with 2-inch batt insulation. The roof, with a 7:20 slope, consisted of 3/8-inch plywood lining with 2-inch batt insulation in the false ceiling, the attic space and 3/8-inch plywood decking with asphalt shingled roofing. Double-glazed windows were located in the east and west walls, involving 41 square feet in each case. The door located on the north gable end of the unit consisting of two 3/8-inch plywood sheathing skins, insulated with 1 1/2-inch batt insulation, involved 24 square feet, while the doors located on the south gable end

Figure 3: Outside view of experimental confinement unit.

Figure 4: Inside view of experimental confinement unit.

of the unit (Figure 5) involved 99 square feet of similar construction.

6.2 Model Parameters.

This study was conducted from 7:00 p.m. September 10, 1973, to 10:00 p.m., September 12, 1973, to determine the parameters required as input into the computer model as well as to determine certain parameters necessary for evaluation of the accuracy of the prediction model. Initially, the intention of the author was to begin on September 10 and run through to September 14, obtaining four consecutive days of data; but, due to experimental failure on September 12, 1973, the data that was collected for 50 hours of successful operation was used.

6.2.1 Ventilation Rate.

Ventilation of the swine unit was by means of an exhaust system where the air was expelled by a 12-inch and a 16-inch constant speed fan located on the east wall of the building. The air was drawn through the attic space by means of slots in the ceiling along the east and west walls.

Discharge ducts with suitable calming lengths and straighteners (60) (Figure 6) were constructed to stabilize the velocity pattern. Velocity probes (Figure 7), connected to a Hastings velocity meter (Figure 8), then were connected directly into a Honeywell 16-point millivolt recorder located at the south end of the facility.

The millivolt reading, as recorded by the chart recorder, was calibrated by measuring the velocity pressure within the discharge ducts down-stream from the fan using a manometer connected to a pitot static tube. The method used to determine the ventilation rate from the velocity pressure was as described by Jorgenson (60). The cross-section

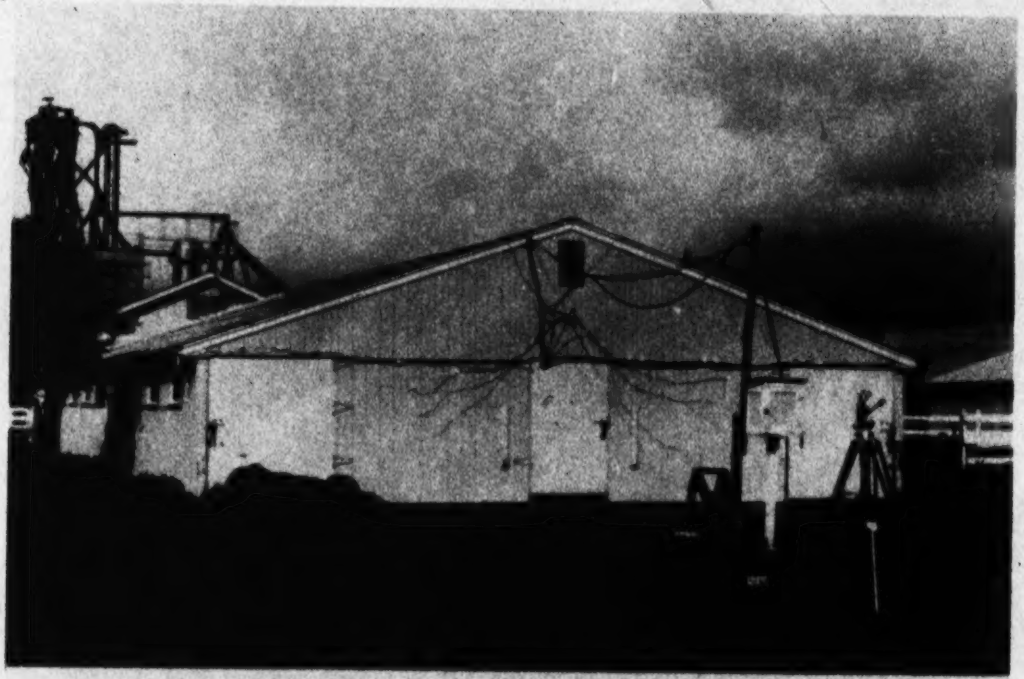

Figure 5: South gable end of experimental confinement unit.

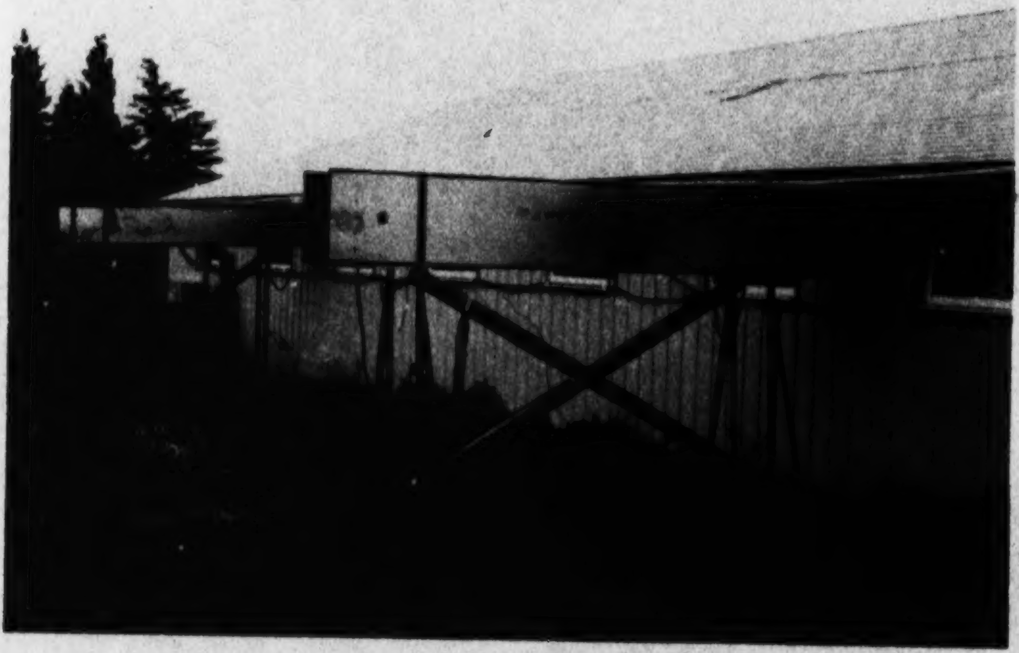

Figure 6: Discharge ducts.

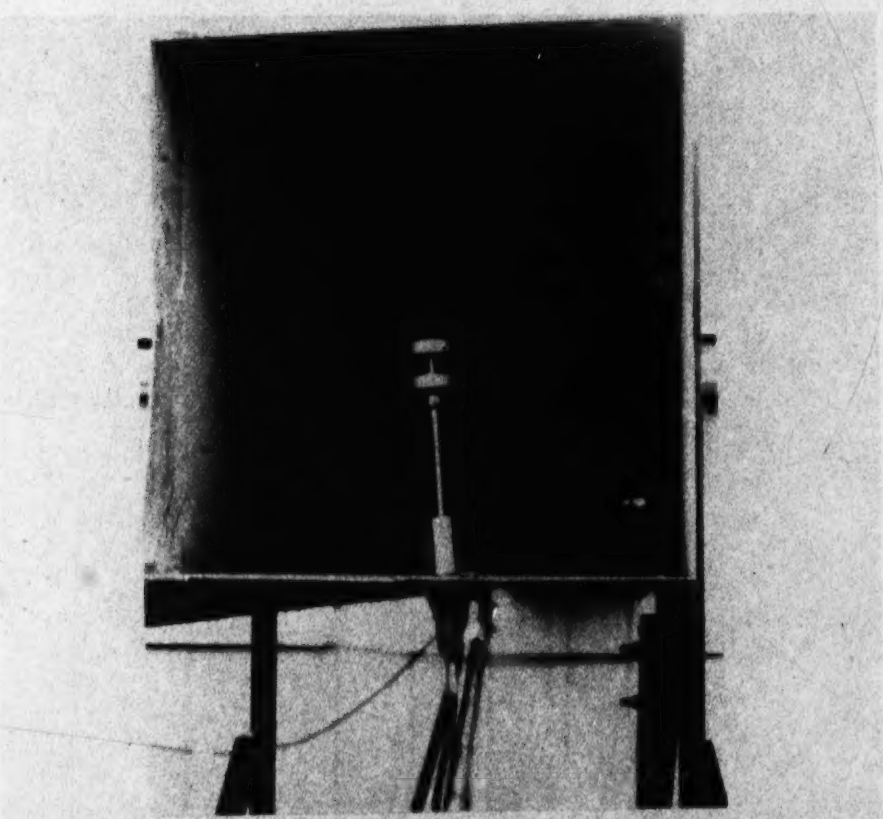

Figure 7: Velocity probe located in discharge duct.

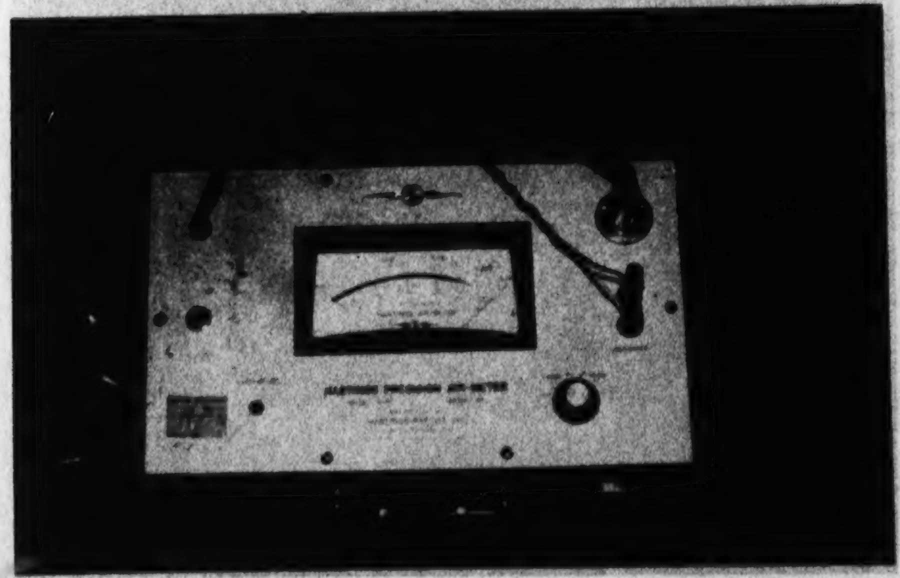

Figure 8: Velocity meter used to measure air flow.

of the discharge duct was divided into 25 rectangles and the velocity pressure measured at the centre of each according to procedures outlined (60). Since the speed of the fans could not be varied, this procedure was carried out several times before the trial run to determine the maximum range over which the ventilation rate varied. This range was found to be 2900 cfm to 3100 cfm. Since the reading on the chart recorder fluctuated well within this range throughout the trial and since the accuracy of the manometer was rated at ±100 cfm, the ventilation rate provided was assumed as 3000 cfm, ± 3%.

6.2.2 Temperature and Relative Humidity.

A total of 102 copper-constantan (16 gauge) thermocouples were used for temperature measurements. Some of the thermocouples were wired directly into a Honeywell 24-point temperature recorder located at the south end of the building (Figure 9), while others were connected in parallel and then wired into the temperature recorder. The temperature recorder then ran continuously giving approximately ten readings for each temperature per hour. Failure of the temperature recording equipment; i.e., failure of the mechanical chopper (DC to AC converter), terminated further readings past 10:00 p.m., September 12, 1973. Error may have been introduced before mechanical failure had been detected, but the recorder was not considered faulty before this time.

Where ambient temperatures were required for the inside conditions, outside conditions and attic conditions, the thermocouples were located in pairs (Figure 10). One of these thermocouples measured the dry-bulb temperature, while the other measured the wet-bulb temperature. The wet-bulb thermocouple lead was covered with a wet wick which extended

Figure 9: Temperature recorder.

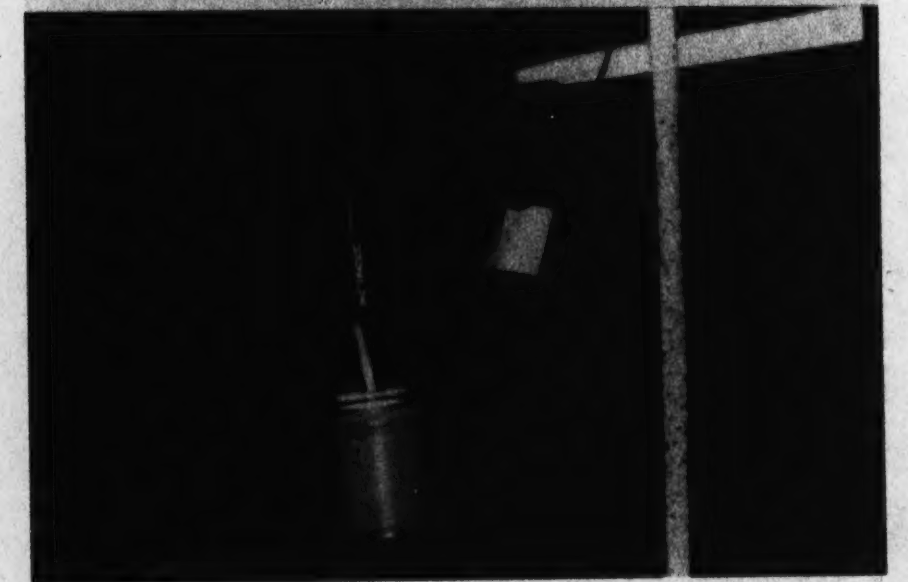

Figure 10: A thermocouple pair used to measure wet-bulb and dry-bulb temperatures.

into a water bath. These wicks were serviced daily because of the prevailing dusty conditions to reduce the wet-bulb temperature error (4,12,38,50). Each thermocouple circuit was calibrated using an ice bath as the standard reference.

Throughout the trial, 40 temperature readings were taken with a sling psychrometer to check the dry-and wet-bulb thermocouples. The deviation of the dry-bulb thermocouple temperatures was in the range of -0.7°F to +1.6°F with a mean deviation of +0.2°F from those taken by the sling psychrometer. Deviation of the wet-bulb thermocouple temperatures recorded was in the range of +0.4°F to 4.4°F with a mean deviation of +2.7°F from those taken with the sling psychrometer. The wet-bulb temperatures recorded were above the psychrometer wet-bulb temperature, a finding also noted by Harman et al (50). This large wet-bulb error most probably was due largely to low air velocities. An air velocity of 500 fpm to 1000 fpm (4,12,60,99) is required for sufficient evaporative cooling to produce a wet-bulb temperature approximately equal to the thermodynamic wet-bulb temperature.

The recorded temperatures of each channel then were divided into hourly groups and the mean temperature of each group was used as the temperature for the time represented. For example, the mean temperature for channel 1 from 7:31 p.m. to 8:30 p.m. was used to represent the temperature for 8:00 p.m. The wet-bulb temperatures were corrected by subtracting 2.7°F from the recorded values.

6.2.2.1 Inside Room Temperature and Relative Humidity.

Inside room dry-bulb temperatures were monitored to evaluate the accuracy with which the model predicted these temperatures. Six dry-bulb thermocouples were connected in parallel and distributed within the building as per Figure 11 and placed half the distance between the floor and ceiling to give an average inside dry-bulb temperature. Care was taken to keep the resistance of the parallel circuits equal (4). As well as this parallel circuit that recorded the inside dry-bulb temperature, a dry-bulb thermocouple, located at each of the two exhaust fans, was connected directly into the temperature recorder. The temperatures recorded by each of these three circuits (i.e. inside average, parallel circuit, 12" and 16" fans) are represented in Figure 12* as well as in Appendix G*.

The temperatures recorded by the thermocouples connected in parallel were used as the inside dry-bulb temperature since they represented the average inside dry-bulb temperature better than either the thermocouple at the 16-inch fan or the 12-inch fan (as noted by temperature measurement with the sling psychrometer). The temperatures recorded at the 16-inch fan deviated drastically from the inside average dry-bulb temperature especially when doors or windows were opened. Between hours 22 and 30, a window on the west side of the building blew open due to stormy conditions with winds gusting to 54 miles per hour. This caused the temperature sensed at the 16-inch fan to rise significantly. Temperatures within the building deviated as much as $\pm 6^{\circ}$F from wall to wall and/or ceiling to floor within the piggery.

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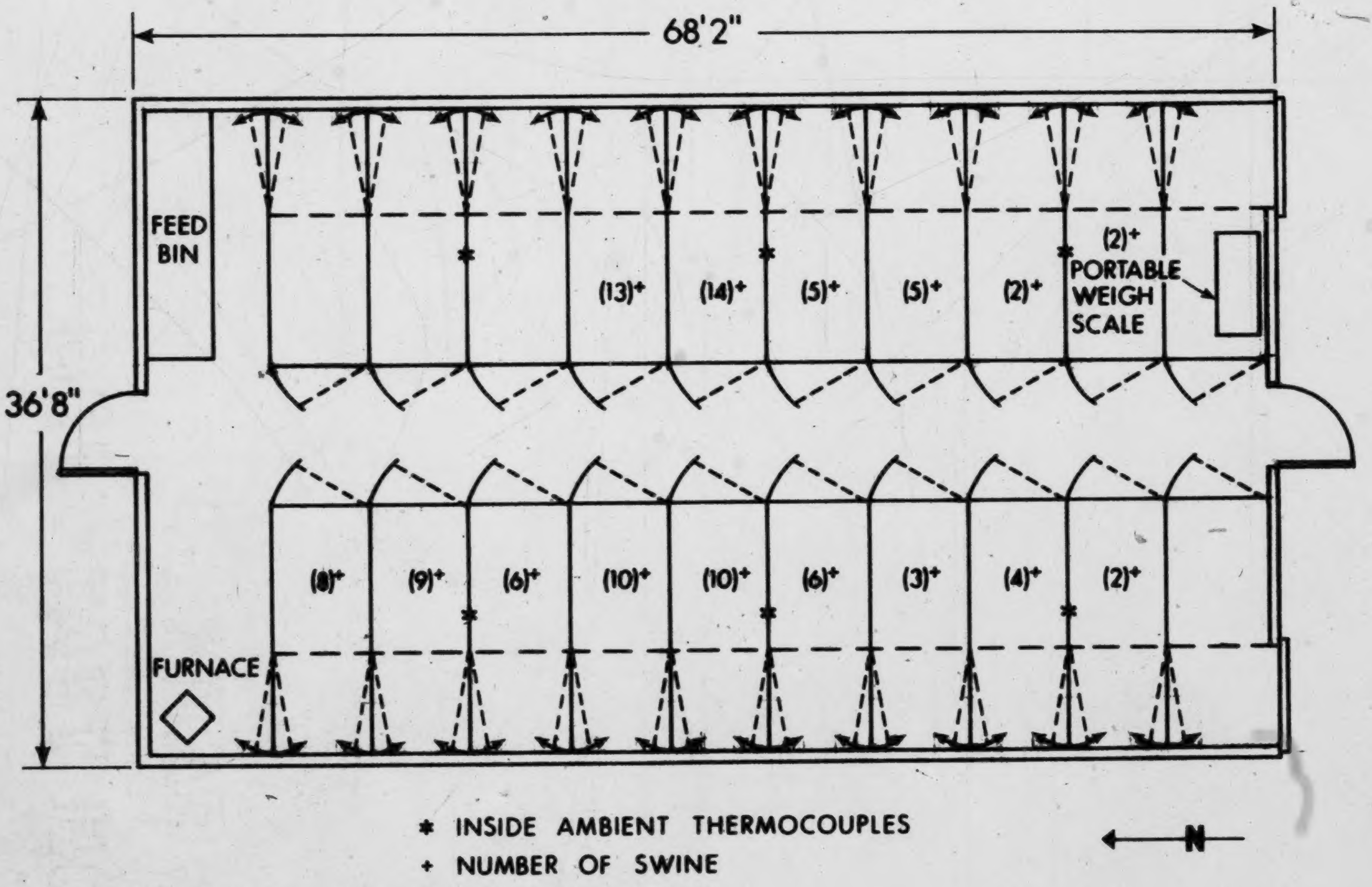
* Note: The time for most figures and graphs is given as hours 1 to 72 inclusive. Time begins at 1:00 a.m. September 10, 1973 represented by hour 1 and continues to midnight, September 12, 1973 represented by hour 72 (See Appendix F).


68'2"
36'8"
FEED BIN
FURNACE
(13)+
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PORTABLE WEIGH SCALE
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(10)+
(10)+
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(4)+
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* INSIDE AMBIENT THERMOCOUPLES
+ NUMBER OF SWINE
N

Figure 11: Floor plan of experimental confinement unit.

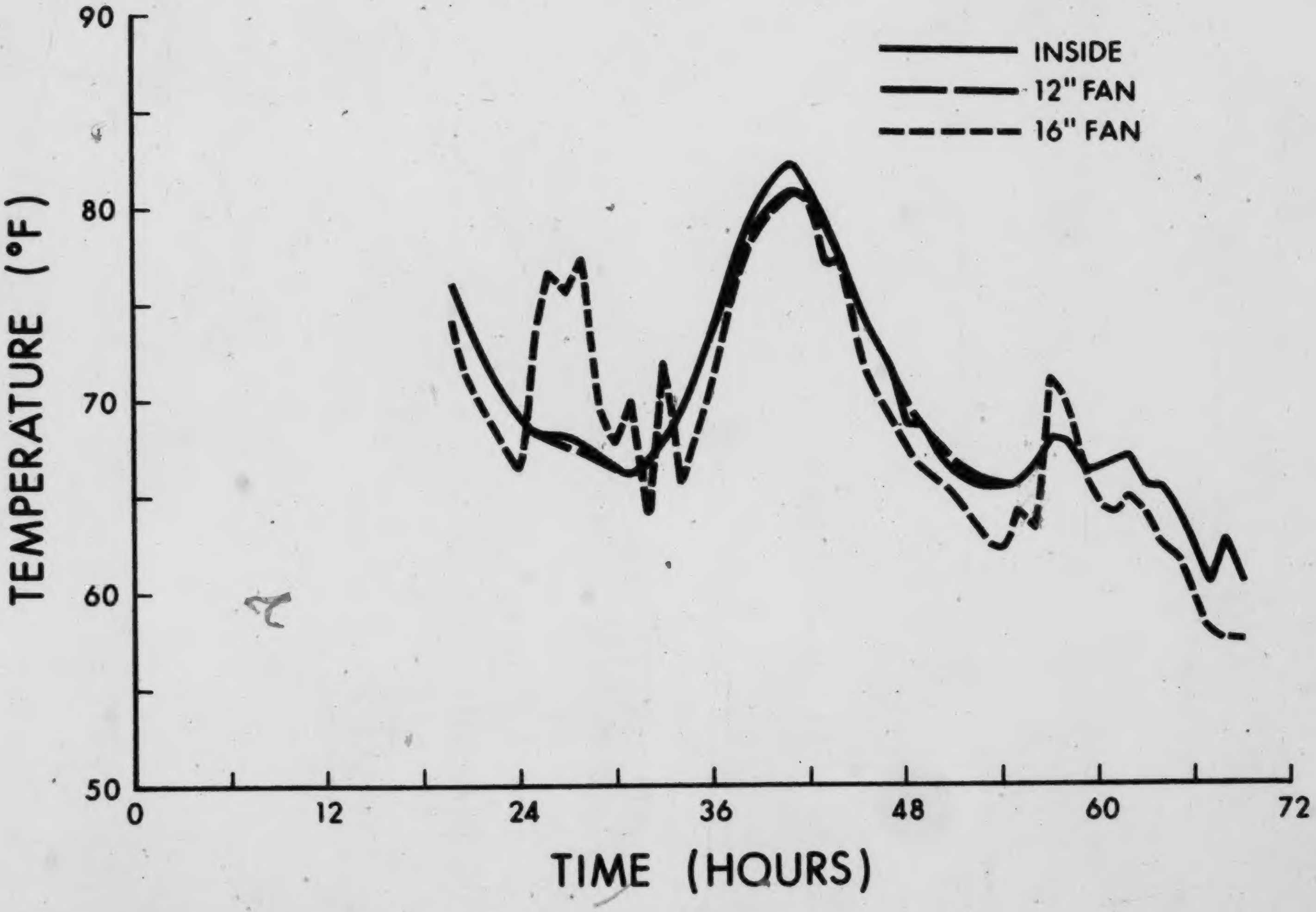


Figure 12: Experimental inside room dry-bulb temperatures.

As mentioned previously, a wet-bulb thermocouple was paired with the dry-bulb thermocouple to monitor the inside ambient wet-bulb temperature. These temperatures then were used in conjunction with the inside dry-bulb temperatures to determine the inside relative humidity according to the algorithm presented in Appendix H.

Since the dry-bulb temperatures recorded by the parallel circuit were used to represent the dry-bulb temperature, the wet-bulb thermocouple temperatures measured by the parallel circuit were also used. The inside relative humidity recorded is presented in Appendix G.

6.2.2.2 Outside and Attic Temperature and Relative Humidity.

The outside dry-bulb and wet-bulb temperatures as well as the attic dry-bulb and wet-bulb temperatures were required as input parameters to the model depending on which was assumed as the incoming or entering air for the ventilation of the confinement unit. The attic dry-bulb temperature was measured with six thermocouples connected in parallel and distributed evenly within the attic. The attic wet-bulb temperature was measured in the same manner with a parallel circuit. The outside wet-bulb and dry-bulb temperatures were measured by a pair of single thermocouples connected directly into the temperature recorder. These outside thermocouples were placed in a white shelter (Figure 13), approximately five feet off the ground, to minimize effects of radiation (4,12,91).

The relative humidity within each region was calculated in the same manner as the inside relative humidity. The dry-bulb temperatures for the attic and outside air and the relative humidity of the attic and outside air are presented in Figure 15 and Figure 16 as well as in Appendix G.

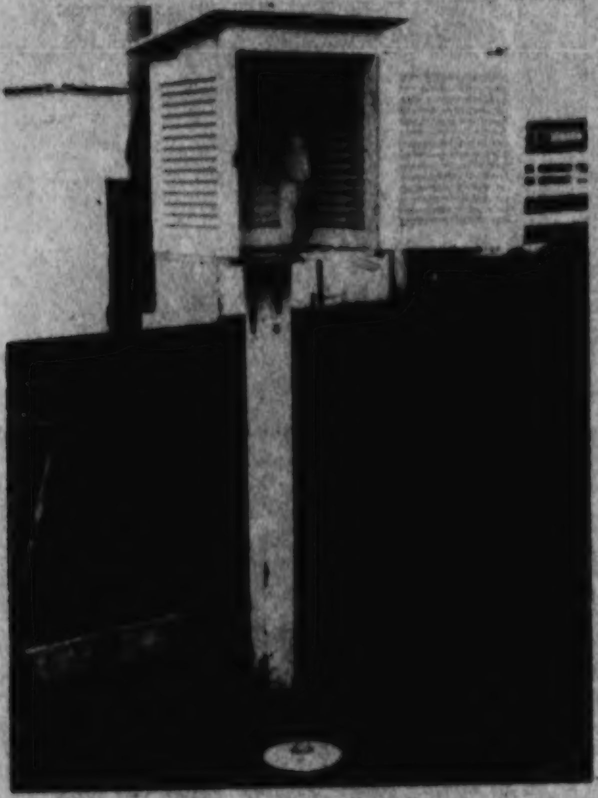


Figure 13: Outside thermocouples located in white shelter.

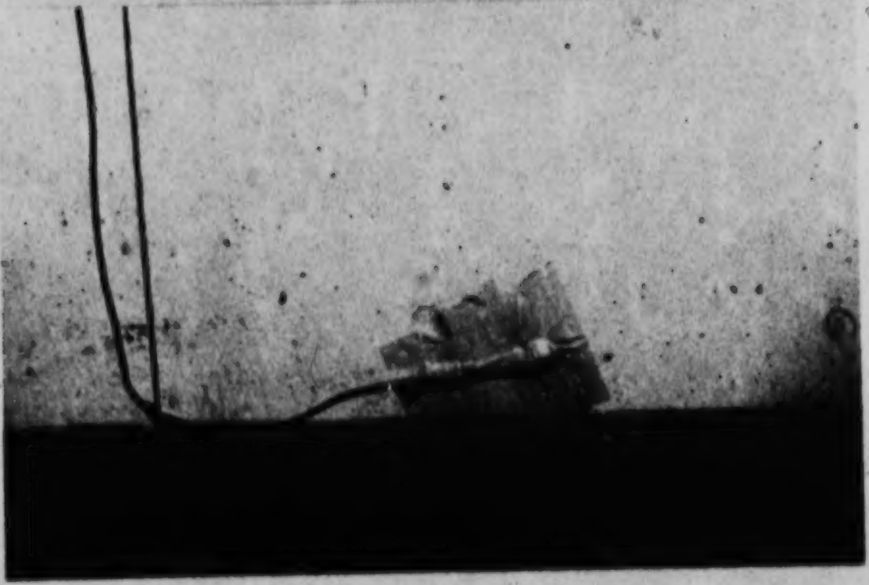


Figure 14: Thermocouple taped to wall surface.

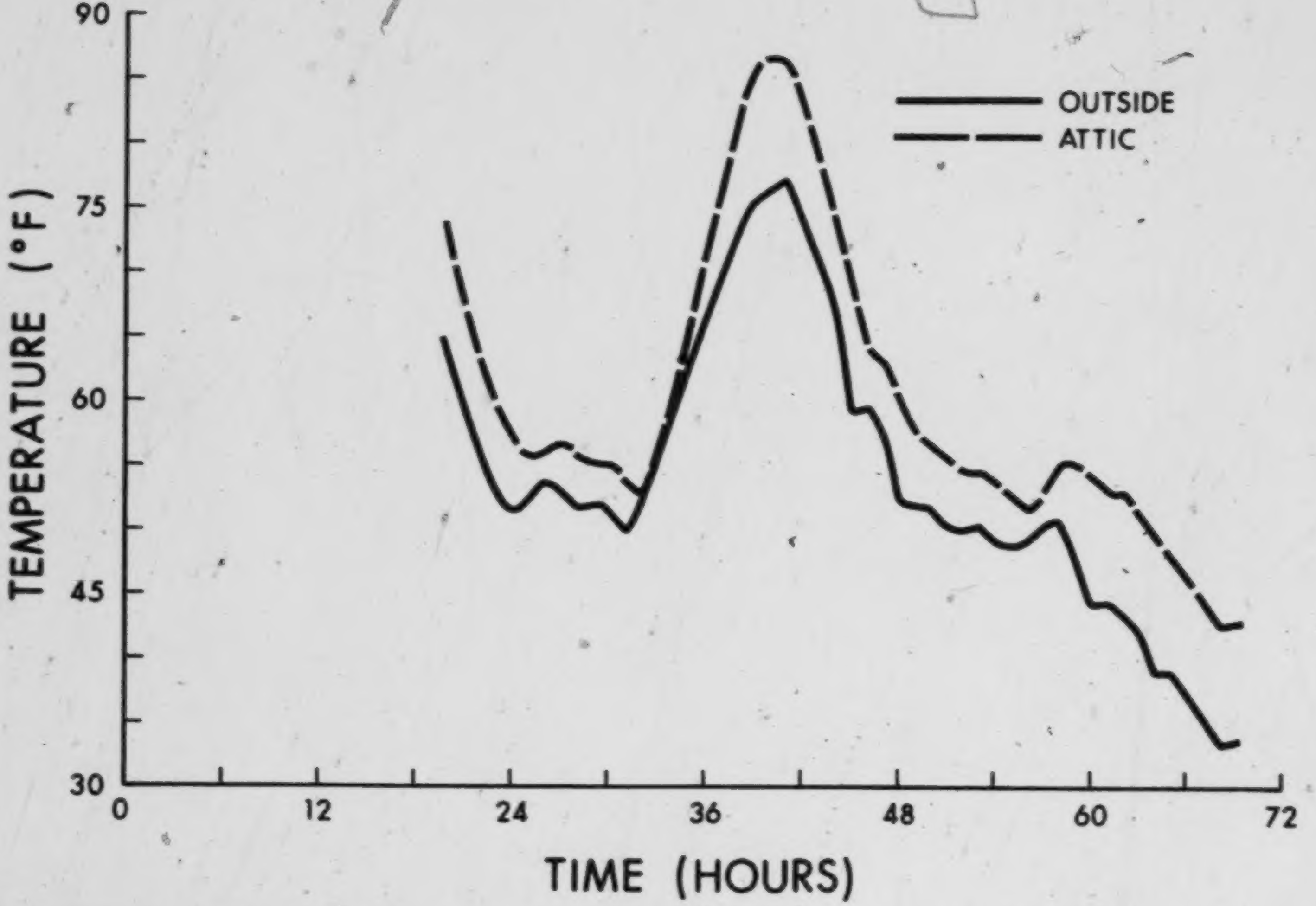


Figure 15: Attic and outside dry-bulb temperatures.

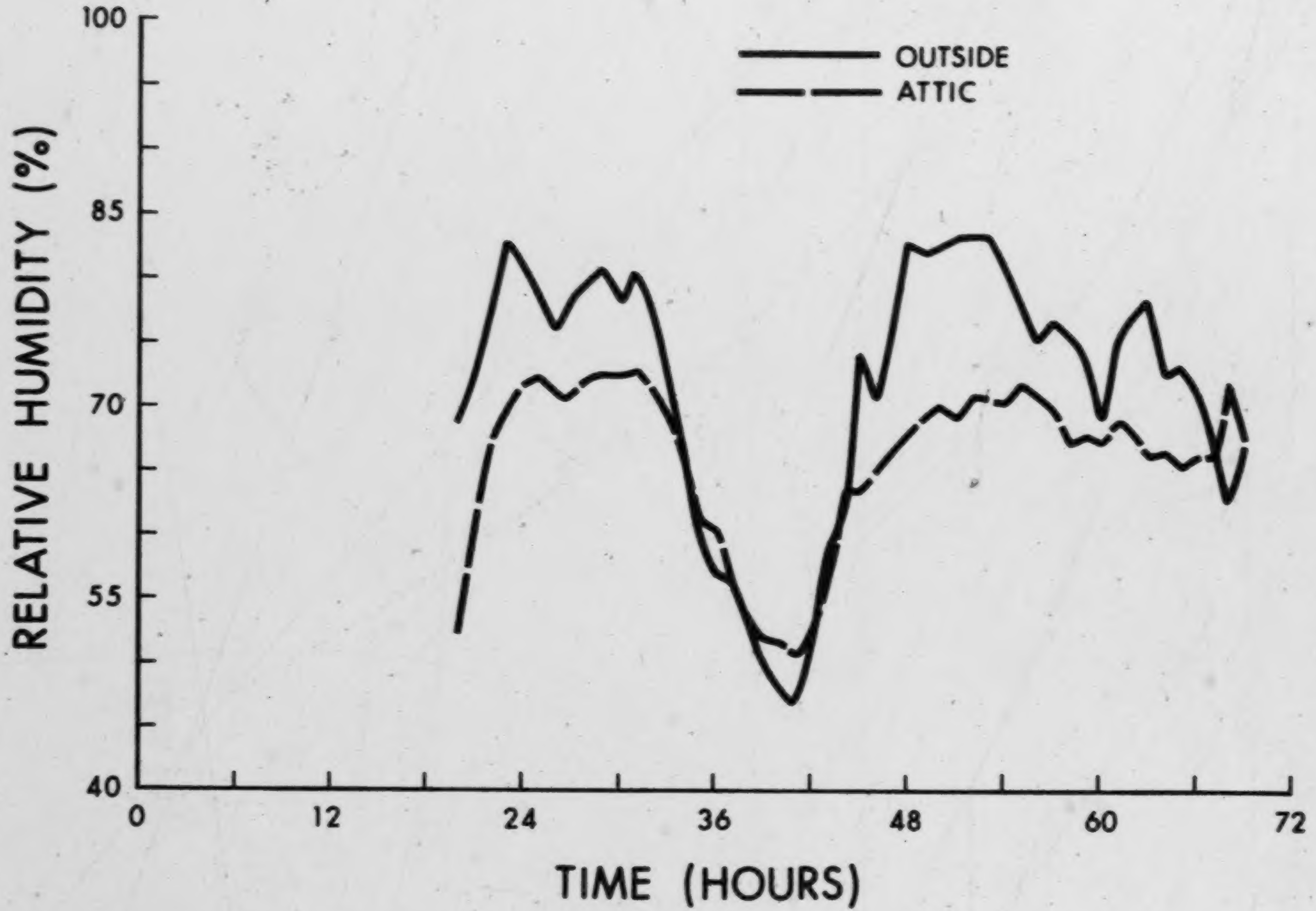


Figure 16: Attic and outside relative humidities.

6.2.2.3 Surface Temperature.

Both inside and outside surface temperatures were recorded for the four side walls of the facility as well as the inside surface temperature of the false ceiling and the outside surface of the east and west sloped portions of the roof. These temperatures are illustrated in subsequent sections in conjunction with those temperatures predicted by the model; the data also may be noted in Appendix G.

Each of the surface temperatures was measured by six thermocouples connected in parallel to give the overall average surface temperature of the component. These thermocouples were attached by means of waterproof tape (Figure 14) whose color was chosen to match the color of the surface as closely as possible (4,91).

6.2.3 Other Weather Data.

Additional weather data were obtained from the local Weather Office located at the Edmonton Industrial Airport, Edmonton, Alberta, for each hour from September 10, 1973,to September 12, 1973. The data included barometric pressure, wind direction, wind speed, station pressure, cloud type and total cloud amount.

The wind direction and wind speed readings were obtained for use in the analyses of the model verification to determine whether large discrepancies could be related to the wind condition. The wind direction was measured in degrees east of true north while the wind speed was recorded in miles per hour (Appendix G).

The station barometric pressure, given in millibars, was converted to inches of mercury using the conversion of one bar equal to 29.53 inches of mercury (4,41). These measurements were then corrected for the elevation and temperature of the facility (60). The corrected readings, as presented in Appendix G, then were used as input to the computer model.

The cloud type and total cloud amount (Appendix G) were required as input parameters to the model. The total cloud amount was presented on a scale of 0 to 10 as obtained from the Weather Station, zero representing no cloud cover and 10 representing total cloud cover. The cloud type was specified for the lowest layer of clouds as this cloud layer appeared to represent the largest proportion of the total cloud cover.

6.2.4 Heat and Moisture Production.

A heater located at the northwest corner of the facility provided the supplemental heat for air-conditioning of the confinement unit. The heat output of this heater, with a rated net total heat capacity of 122,000 British Thermal Units per hour, was monitored by a mechanical service recorder which was sensitive to vibration. The recorder was mounted on the back of the furnace (Figure 17) where maximum vibration of fan movement was detected. Prior to the trial, the pendulum movement of the service recorder (i.e. fan movement) was calibrated against the actual heater operation. This established that the heater operated for an average of two minutes less than the fan operated. Using the pendulum movement and the net heater output, the heat output per hour was determined. The heater did not commence operation until hour 68, at which time 16,000 British Thermal Units of heat were added to the facility per hour.

To estimate the heat and moisture output of the animals and surroundings, the number of animals and their weights were required for the applicable regression equations. A total of 99 swine were confined

Figure 17: Service recorder mounted on heater unit.

and distributed within the building as per Figure 11. The individual weights of the animals were as presented in Appendix G. These animals were weighed on September 10, 1973, before the trial commenced.

6.2.5 Physical Data of Structural Components.

The physical data required as input for the model included thickness, conductivity, density, specific heat and resistance of the radiation path whenever applicable (thermal resistance when there was negligible heat storage) for all layers of each structural component. As mentioned previously, the structural components included the following layers: aluminum siding, plywood, batt insulation, air and asphalt shingles.

The data for each layer of each structural component were obtained from numerous references (2,3,4,19,40,60,96,99,102). There was an appreciable variation between different sources as to the specific applicable values; these deviations are considered in the sensitivity analysis. In all cases the individual layers were inspected and a value that would best represent the material was assumed. The data from the manufacturers were not available while the techniques to determine these values were very detailed and expensive.

The thermal data for aluminum siding over a flat surface (plywood sheathing) varied widely depending upon the amount of ventilation of the air space beneath the siding, whether the air space is reflective or non-reflective, and upon the thickness, type and application of insulating backing-board used. The 0.0027-foot thick siding (measured by micrometer) was assumed to have a thermal conductivity of 128 BTU/(hr)(ft^2)(^{o}F) per foot of thickness, a density of 171 lb/ft^3, and a specific heat of 0.214 BTU/(lb)(^{o}F). Departures of ±50 percent, or more, from the values assumed may occur (4).

The 3/8-inch (0.0313 ft) plywood sheathing was assumed to have a thermal conductivity of 0.066 BTU/(hr)(ft^2)(^{o}F) per foot of thickness, a density of 34 lb/ft^3 and a specific heat of 0.29 BTU/(lb)(^{o}F). These values did not differ between the reference sources used to any extent; however,moisture content, age and type of material could influence the specific physical parameters.

For the 2-inch and the 1 1/2-inch (0.1667 ft and 0.125 ft) batt insulation, stated values may have deviated from those assumed by $\pm$50 percent, depending again on moisture content, age and type of material. After close inspection, the values assumed were a thermal conductivity of 0.022 BTU/(hr)(ft^2)(^{o}F) per foot of thickness, a density of 3.25 lb/ft^3 and a specific heat of 0.18 BTU/(lb)(^{o}F).

The asphalt shingles, with an average thickness of 0.0217 feet, were assumed to have a thermal conductivity of 0.43 BTU/(hr)(ft^2)(^{o}F) per foot of thickness, a density of 70 lb/ft^3 and a specific heat of 0.22 BTU/(lb)(^{o}F). These values might deviate from the assumed values by $\pm$ 50% depending on the age and type of material considered.

The thermal resistance of the air space within walls was assumed as 0.85^{o}F/BTU/(hr)(ft^2) per foot of thickness. All reference sources were within $\pm$ 5% of this resistance value.

6.2.6 Other Parameters.

There were a number of parameters necessary as input data (Appendix D and E) which had to be determined. Several references (2,3,4,8,36,50,60,93,96,99) were used to determine these values. The departure from the assumed values for many of these data were fairly large, but after considering the variations associated with each, a value was assumed using best judgement. The deviations are considered later in the sensitivity analysis.

The emissivity and absorptivity factors for all the outer surfaces as well as those for the attic surfaces were required. As the outer surfaces of all the walls were a cream-colored paint, the emissivity factor was assumed to be 0.92 and the absorptivity value to be 0.40. The asphalt shingles were assumed to have an emissivity factor of 0.93 and an absorptivity factor of 0.82. The upper attic surface, composed of plywood sheathing, was assumed to have an emissivity factor of 0.90 while the lower attic surface, paper cover on the batt insulation, was assumed to have an emissivity factor of 0.92.

The thickness of the attic space was determined as 39 inches (one-half the gable height).

The windows located on the east and west walls of the building were 1/8-inch double-glazed sheets with polynomial coefficients for calculation of absorptance and transmittance as given in Appendix G. The overall heat transfer coefficient for these windows was assumed as 0.66, with a variation from this value due to wind speed effects on the individual air film coefficients for heat transfer by convection and radiation. The inward-flowing fraction of the radiation absorbed by the inner window-pane and that by the outer window-pane were calculated according to procedures outlined in Appendix H.

The heat transfer coefficients for the outer air film, inner air film and the air film within the double-glazed sheets can vary with varying forced air motion caused by wind on the outdoor surface, air induction devices or fans at the indoor surface, and the direction of air movement. For still air conditions, a value of 1.46 BTU/(hr)(ft^2)(^{o}F) was assumed for a vertical air film. This value can rise to as high as 3.0 when forced convection is produced by fans, induction units, etc. The value for a horizontal film (air movement upwards) was assumed as 1.63, a horizontal film (air movement downwards) as 1.08, an air film at 45 degrees (air movement upward) as 1.60, and air film at 45 degrees (air movement downward) as 1.32. For outside surfaces, the heat transfer coefficient was assumed as 4.0 for summer conditions (wind of 7.5 mph).

The shading coefficient for the windows was assumed as 0.90. As for the clearness number, the range for industrial areas is 0.7 to 0.9 depending on the type of industry, while for non-industrial areas this variable may be as high as 1.1. As the area in which the experimental facility was located is non-industrial, but still within city limits, the clearness number was assumed as 1.0.

The ground reflectivity was assumed as 0.2, this value being considered as representing the conditions at the time. The value for a/h_o (a equals the absorptance of the surface for solar radiation and h_o equals the coefficient of heat transfer by radiation and convection at the outer surface) was assumed as 0.15 for light-colored surfaces as suggested by several of the reference sources mentioned above. The same sources noted that 0.30 represents the maximum value that is likely to occur for this parameter.

In addition to these assumed parameters, the intensity of solar radiation was measured by a pair of pyrheliometers (91,99); one (Figure 18) measured the direct radiation normal to the sun's rays, while the other (Figure 19) measured the total horizontal radiation. The

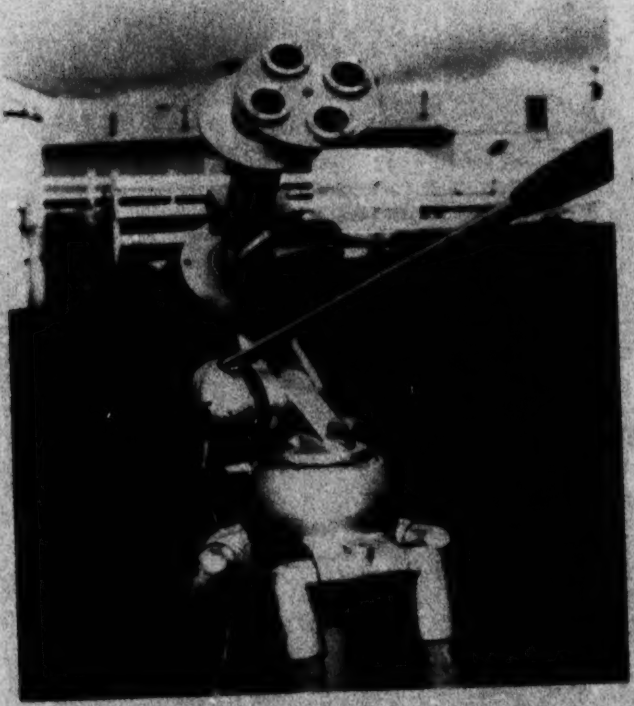


Figure 18: Pyreliometer to measure the direct normal radiation.

Figure 19: Pyreliometer to measure the radiation on a horizontal plane.

direct normal pyrheliometer was connected to a digital voltmeter and readings taken manually, while the horizontal pyrheliometer was connected directly into the millivolt recorder.

6.3 The Computer Simulation.

The validation simulation trial was conducted between September 10, 1973 and September 12, 1973; therefore, the simulation period was three days (72 hours). As mentioned previously most of the parameters associated with the model were collected for 50 hours (hour 20 to hour 69), but since the model must begin at 1:00 a.m., the complete three days were simulated by the computer model. This required assumptions for temperature for the time when they were not determined experimentally. These were determined by using the temperatures at the Edmonton Weather Station.

The swine finishing barn used as the experimental total confinement unit was ventilated for removal of the heat load with thermostatic controls for temperature maintenance. To determine the ventilation rate for optimal moisture removal, 70 percent relative humidity was assumed (8). The simulation model maintained the ventilation rate required to remove the resultant heat load within ± 3 percent specified by the author as the accuracy required.

The outside temperature was assumed to be the temperature of the incoming or entering air for ventilation purposes. The location of Edmonton is 53.34 degrees North latitude and 113.31 degrees West longitude. Edmonton's time zone number is seven and, during the month of September, the city is under daylight saving time.

The surface tilt and azimuth angles were checked by the surveying crew of the Physical Plant Department, University of Alberta. The building azimuth was found to be within 1% of north-south while the surface tilt of the walls was within 1% of being vertical.

Most of the work involved with the computer was performed in conversational mode from an IBM Model 2741 communication terminal using disk-file and magnetic tape. The input data collected then was modified according to input requirements (Appendix D and E) and prepared in the proper format as presented in Appendix I. The program then was processed using a Fortran G compiler on an IBM System 360 Model 67 dual-processor computer using Virtual Memory facilities and the Michigan Terminal System at the University of Alberta Computing Centre. The output is presented in Appendix J in the format discussed previously. The computer time and costs are presented in Appendix K for the three-day simulation period.

7. DISCUSSION OF THE VALIDATION RESULTS

7.1 Initial Validation.

Initially, the heat blanace equations were solved simultaneously using the outside temperature to represent the outside conditions as outlined by Mitalas (73). The results using this method are referred to as Model A (Appendix J) throughout the remaining discussion.

The American Society of Heating, Refrigerating and Air-conditioning Engineers (4) stated that the transfer function approach as used in this model is particularly well suited for using the sol-air temperature to represent outside conditions. For this reason, the model was altered slightly to use the sol-air temperature to represent outdoor conditions, still using the heat balance equations which included convection and radiation at each surface. The results using this method are referred to as Model B throughout the remaining discussion. This method is not entirely correct because the sol-air temperature is the temperature of the outdoor air which, in absence of all radiation exchanges, would give the same rate of heat entry into the surface as would exist with the actual combination of incident solar radiation, radiant energy exchange with the sky and other outdoor surroundings, and convective heat exchange with the outdoor air. To make the changes necessary to accurately include sol-air temperature, the heat balance equations would have required major modifications. These modifications were not made, even though sol-air temperature was used to represent the outside conditions in Model B, but Model B was included to illustrate the magnitude of the effect of using sol-air temperature.

7.1.1 Numerical Component Data.

The physical data were the same for both Model A and Model B as presented for Model A in the sample output (Appendix J).

The output includes a listing of the physical numerical data entered as input and the calculated overall thermal conductance, BTU/ (hr)(ft^2)(^oF), for the walls, roof and doors. The values for the horizontal roof are 'dummy' values, as mentioned previously, but these do give an idea as to the data for a horizontal roof as specified by the user. The overall thermal conductance values given are 0.107, 0.103 and 0.151 for the walls, roof and doors respectively,indicating that the rate of heat flow through the doors was greater than that through the walls which,in turn,was greater than that through the roof.

The z-transfer coefficients are calculated on the basis of surface temperatures given for each surface and for a ramp-type input and a sampling time interval of one hour. There are five sets of z-transfer function coefficients given for each component with, in each case, three being non-zero. This indicates that for each component the heat transfer of the slab is affected by the surface temperature and the heat flux history of the three preceding hours.

7.1.2 Solar Parameters.

The solar parameters are the same for Model A and Model B. These are presented in Appendix J for each component and component orientation for each hour of the simulation period. As noted previously, the parameters given for the horizontal roof are artificial and are not included in the psychrometric calculations within the model since zero is entered as the area for the horizontal roof. These values were used, however, to compare the observed solar radiation on a horizontal surface to those predicted by the model.

At the top of each page of output pertaining to each component orientation, the latitude and longitude of the location were recorded as well as the time zone number and daylight saving time. The time zone number indicates the time behind Greenwich Civil Time, a difference of four minutes occuring for each degree difference in longitude (99). Furthermore, the equation of time and declination are given as calculated within the program.

The clock time, solar time, solar altitude, solar azimuth and intensity of the direct normal solar radiation incident were the same for all components throughout the simulation period. Inspection of these variables (Appendix J) shows that the solar time, indicating the time of day in hours with respect to solar noon, was zero at approximately 1:30 p.m. of each day. This appears to be realistic considering daylight saving time and that Edmonton is west of 105 degrees west longtitude; that is, with no daylight saving time and at a location of 105 degrees west longtitude, solar noon would have occurred at 12:00 noon (clock time). At solar noon the solar altitude was maximum and the solar azimuth was zero; the altitude angle being the angle in the vertical plane between the sun's rays and the projection of the sun's rays on the horizontal plane and the azimuth angle being the angle in the horizontal plane measured from south to the horizontal projection of the sun's rays. Since solar radiation calculations must be made in terms of solar time, the accuracy of these values was necessary.

The direct normal solar intensity and the intensity of the solar beam on a horizontal surface, as determined experimentally, were compared to those calculated by the program. The direct normal solar intensity was recorded in the data output for the solar parameters of each component, while the intensity on a horizontal surface was the total solar intensity on the horizontal roof (solar load on horizontal roof).

The observed and predicted values for solar intensity are summarized in Appendix G. The observed intensities and the calculated intensities were not identical in all cases but the general trends and peaks were similar. These differences may be associated with the differences in the cloud cover that occurred at the time and point of measurement and the data obtained from the Edmonton Weather Station to represent the overall sky cloud cover. The solar intensity readings would have been much more accurate had the readings been constantly recorded on a chart recorder, but a tracking device to follow the sun was not available. For this reason, the experimentally determined readings were dependent upon the cloud cover over the sun at the moment of monitoring and do not represent the actual hourly average values.

The intensity of the direct beam on the component surface and the total solar load (including the direct normal intensity, sky diffuse intensity and ground diffuse intensity) also were presented for each component and each component orientation. The values, given in BTU/(hr)(ft^2) were an accurate hourly average except for irregularities that may have occurred due to variation in cloud cover for any given moment. The total solar load on each outer component surface was a maximum when the sun directly faced the component; for example, on the east wall surface the solar load was maximum in the forenoon while on the west surface the solar load was maximum in the afternoon. The solar load on the south wall surface was consistently higher than that on the north wall surface. These trends indicated that the solar calculations accurately followed expected trends and represented the general solar heat loads on the building.

The solar heat gain factors, for calculations of the heat transfer through the windows, appeared reasonable with maximums on the east wall in the forenoon and on the west wall in the afternoon. Also, the sol-air temperatures showed an increase when the solar load on the respective outer surface increased.

Comparisons of solar data were made to data presented by Stephanson (93). From these comparisons, the solar calculations were observed to follow expected trends with a fairly high degree of accuracy. These values then could be used successfully to calculate the dynamic thermal characteristics within the total confinement unit.

7.1.3 Thermal Properties.

The thermal properties included, for analysis purposes, the inside dry-bulb temperature, the inside relative humidity, the outside surface temperature and the inside surface temperature. These are discussed for both Model A and Model B since variations did occur. The data for Model A (outside temperature representing outside conditions) are presented in the sample output (Appendix J), whereas the actual output data for Model B were not included due to the large amount of data that would be required for inclusion. The temperature data considered is presented in Appendix G giving comparable values for the observed, Model A and Model B.

The data were analyzed to find the correlation between observed and predicted values by finding the coefficient of simple correlation and to test for the similarity of the means by utilizing the paired two-tailed t-test for significance (49,108). The differences or residuals also are discussed subsequently for some of the variables where differences in the observed and the predicted values occurred (49).

7.1.3.1 Inside Room Dry-Bulb Temperature.

The inside room dry-bulb temperature predicted by both Model A and Model B are illustrated in Figure 20 together with the observed inside dry-bulb temperature for the 50-hour monitoring period.

The correlation coefficient between the observed and Model A temperatures and between the observed and Model B was 0.97. This would indicate that the model accurately predicted the cycling nature of inside room dry-bulb temperatures.

The t-value of Model A and observed temperatures was -13.58 while the t for Model B and the observed was -12.55. The hypothesis that the difference between the means of each population is zero was rejected at the 99% confidence level in both cases. Therefore, the predicted and the observed values did not belong to the same population.

Figure 20 indicates that the model predicted the inside dry-bulb temperature accurately between hour 35 and hour 42 (11:00 a.m., September 11 to 6:00 p.m., September 11). During this period, the ingoing air temperature (outside temperature) was fairly high (above 60^{o}F). During the evenings when the solar load was zero (no sun) and the sol-air temperature was equal to the outside temperature, both models predicted the same inside dry-bulb temperature while, during the day when the sol-air temperature was higher than the outside temperature, Model B predicted the dry-bulb temperature slightly more accurately, but not significantly so.

During the night and a cold rainy day (September 12, 1973) the residuals (differences between the predicted and the observed values)

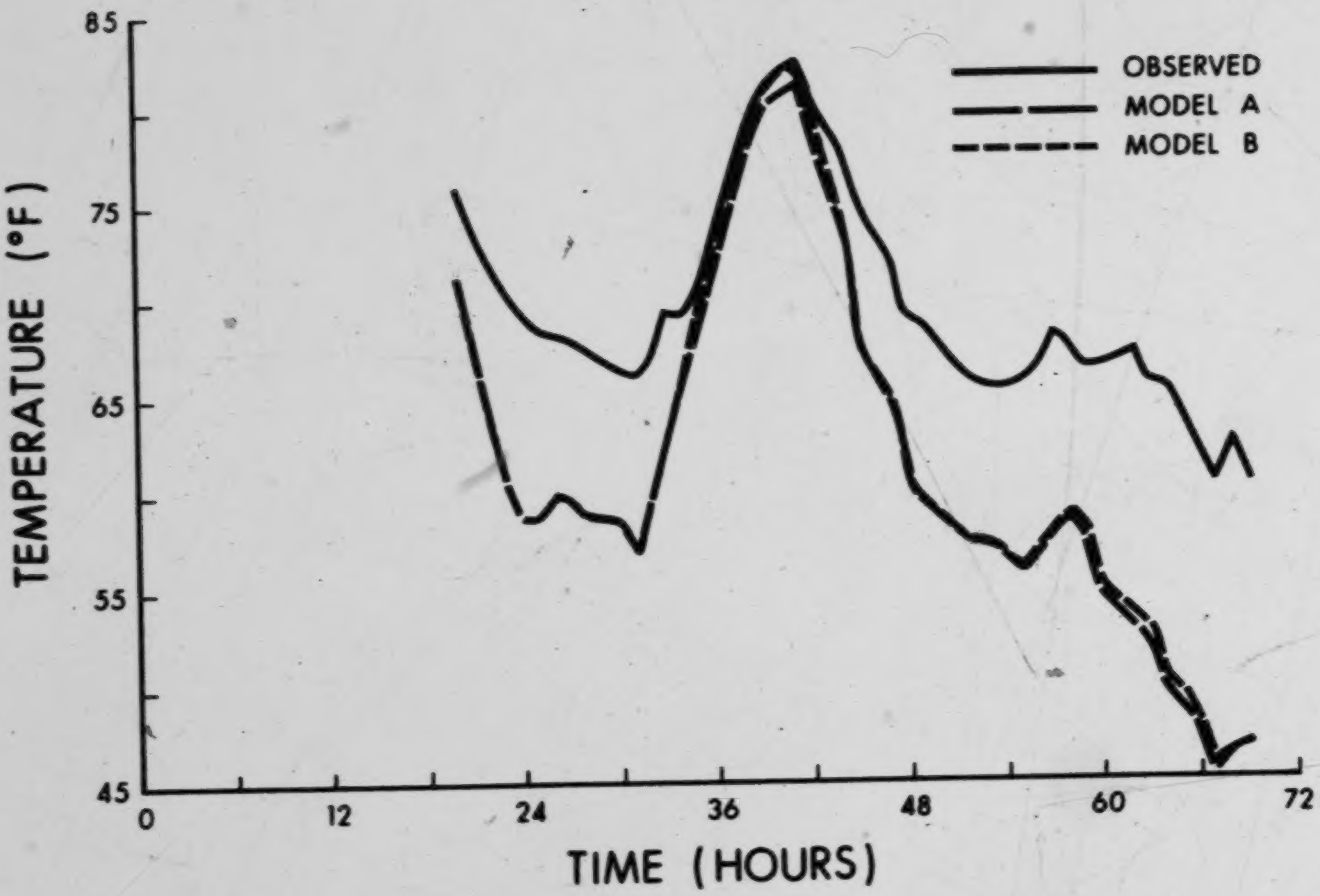


Figure 20: Inside room dry-bulb temperatures.

were large. The model predicted temperatures that were approximately 15°F lower than the observed during the last few hours of simulation. These large residuals may have been partially due to the very wet conditions accompanied by low temperatures. In this case, the theoretical basis for the model apparently was inaccurate. The heat transfer of wet surfaces should account for the evaporation rate of water and the water heat storage of the water layer (4,73). Average experimental temperatures also may have contributed to error in validation as temperature gradients were large from floor to ceiling and from wall to wall as indicated by psychrometer readings. The recorded data were the average readings of the thermocouples located within the facility.

The model predicted the cyclic behavior of the inside dry-bulb temperature with a highly significant degree of accuracy ($P<0.01$). The mean difference for temperature prediction of Model A versus observed was -8.3°F (range -16.2 to -0.8°F) while for Model B versus observed was -7.9°F (range -15.9 to +0.3°F).

Similar results were obtained by Wilson (103) using a finite difference simulator to model the heat transfer through walls, ceiling and floor on a small test shelter with no inside heat sources. The average deviation between the observed and predicted was 4 to 5°F. This researcher also found the computer simulator to be a satisfactory predictor of inside temperatures with best accuracy for the period of highest temperatures, as also noted with this model.

7.1.3.2 Inside Room Relative Humidity.

Examination of Figure 21, which presents the inside room relative humidity for the observed, Model A and Model B, indicates the

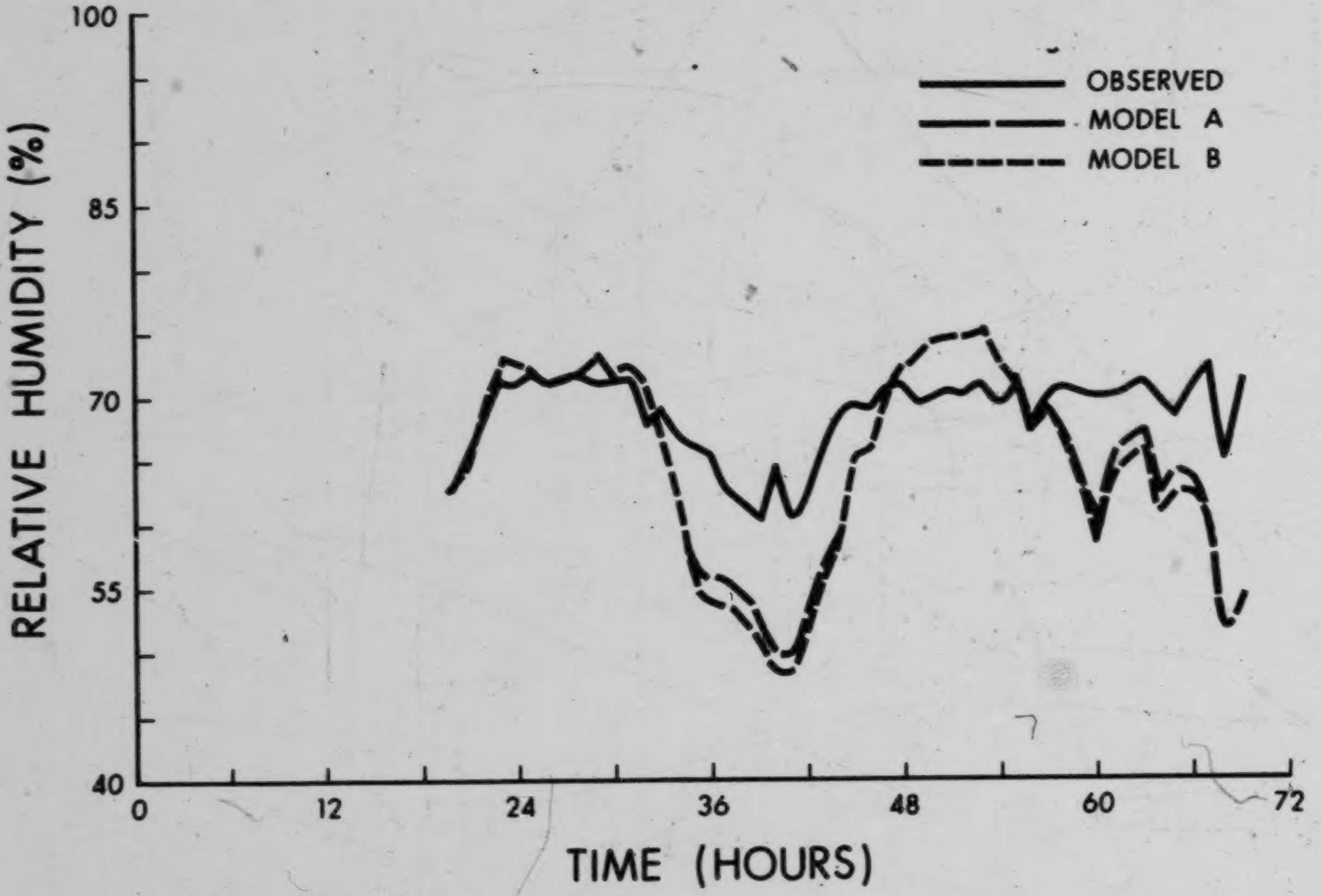


Figure 21: Inside room relative humidities.

accuracy with which the model predicts relative humidity.

The correlation coefficient for both Model A and Model B versus the observed was 0.76, indicating that the predicted and the observed relative humidities were well in step (P 0.01). However, the correlation is not as high as that for temperature prediction. The value for t for Model A versus the observed was -4.26 and that for Model B versus the observed was -4.67. This would indicate that the null hypothesis that the mean of the predicted and the mean of the observed relative humidity was the same could be rejected at the 99% confidence level, however, with less confidence than found for inside dry-bulb temperature.

The relative humidity prediction was accurate only for the first 13 hours of validation (Figure 21). From hour 33 (9:00 a.m., September 11) the relative humidity prediction began to deviate from the observed. This deviation appeared to be larger during the day when the solar load was not equal to zero. The mean difference between Model A and the observed was -3.3% (range -16.6% to 4.4%) relative humidity while the mean difference between Model B and the observed was -3.9% (range -16.7% to 4.4%) relative humidity.

This analysis showed that the inside relative humidity prediction was slightly more accurate than the inside dry-bulb temperature prediction, but the cyclic behavior was not predicted as well.

Phillips and Esmay (85), using a mathematical model to simulate inside environmental conditions in a laying house, found in their verification trials a mean deviation of 5.1% between actual and predicted relative humidity. They also found that maximum deviations occurred when outside or inside conditions were changing rapidly.

7.1.3.3 Inside Surface Temperature.

The data, as plotted in Figures 22 to 26 for the observed,

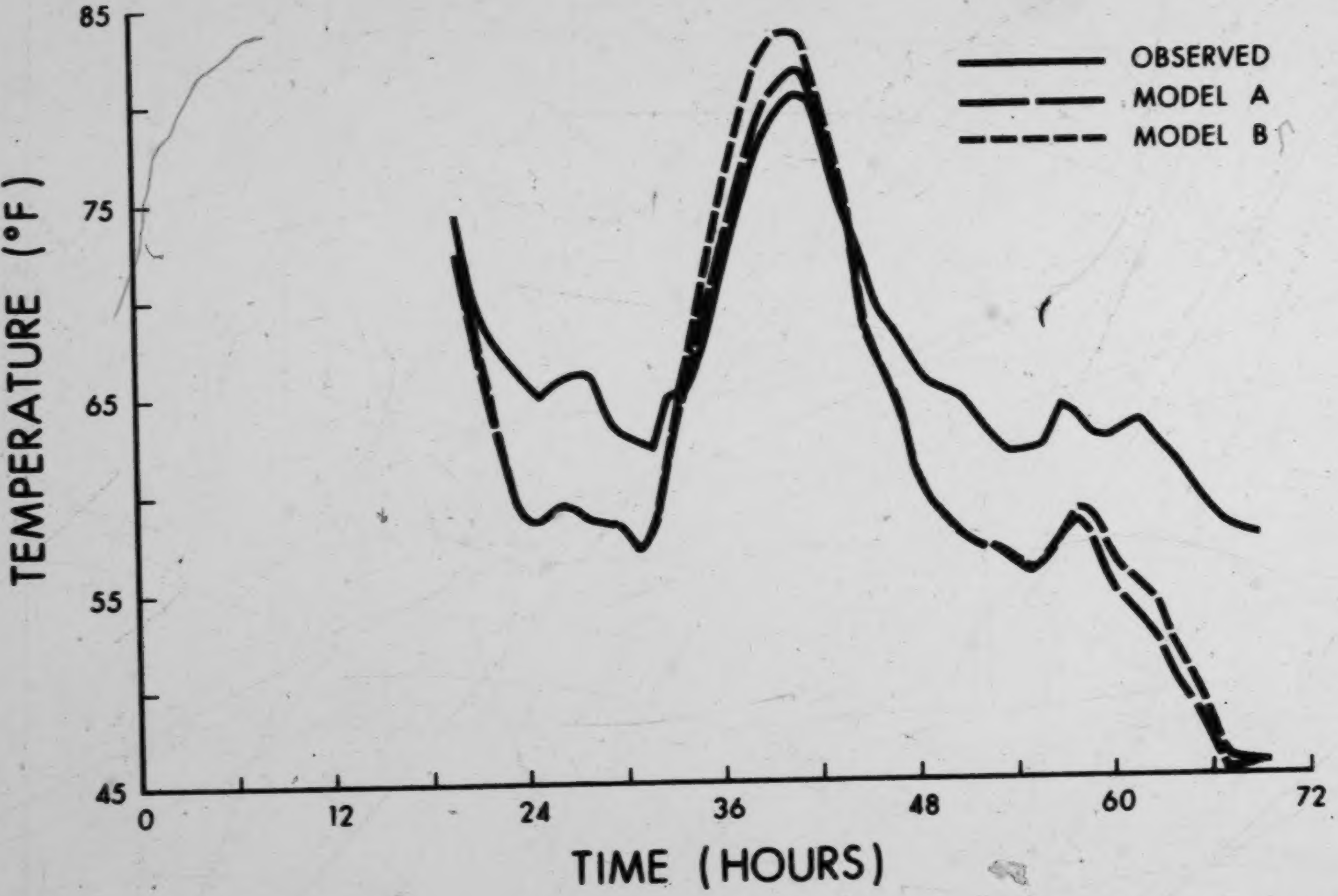


Figure 22: South wall inside surface temperatures.

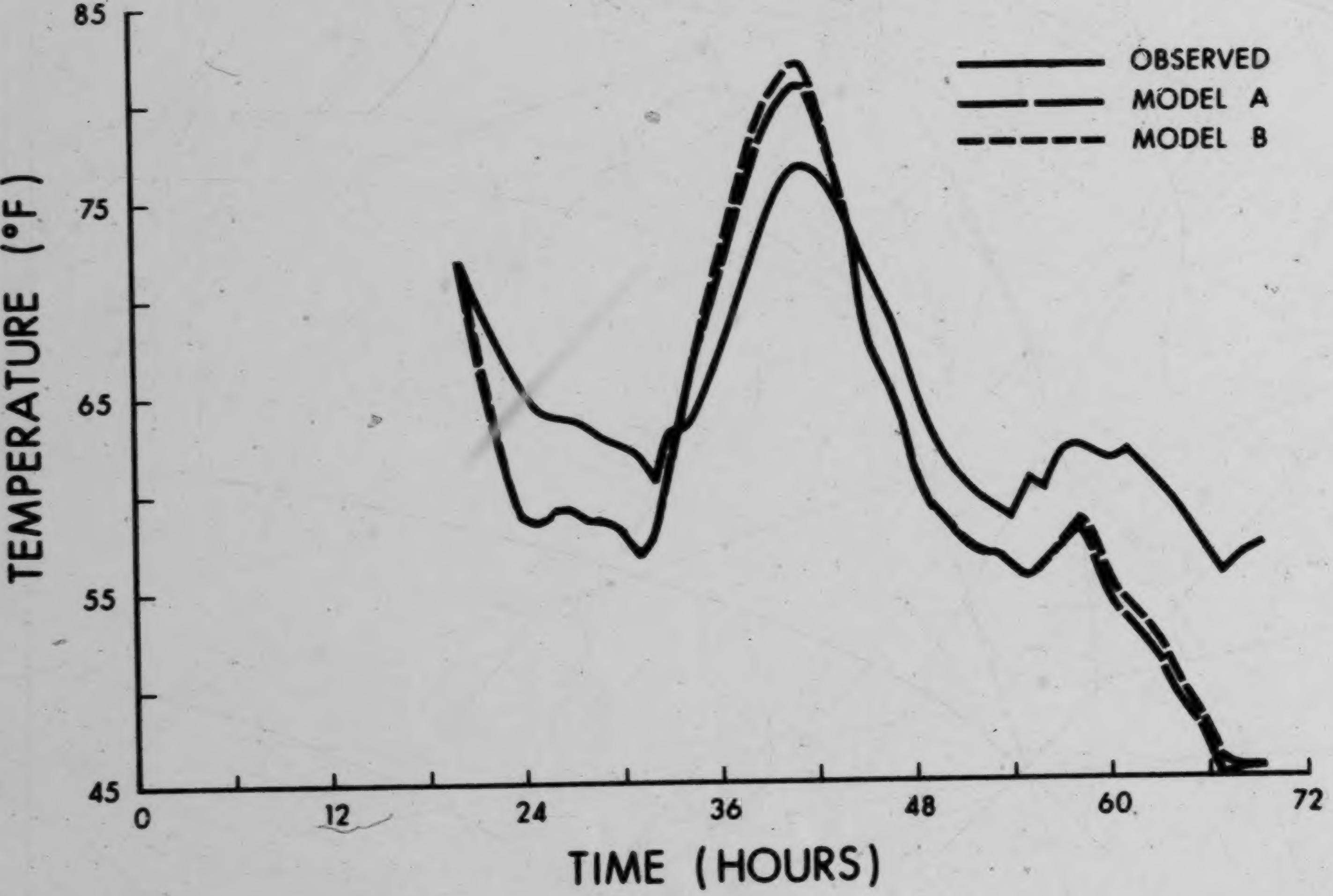


Figure 23: North wall inside surface temperatures.

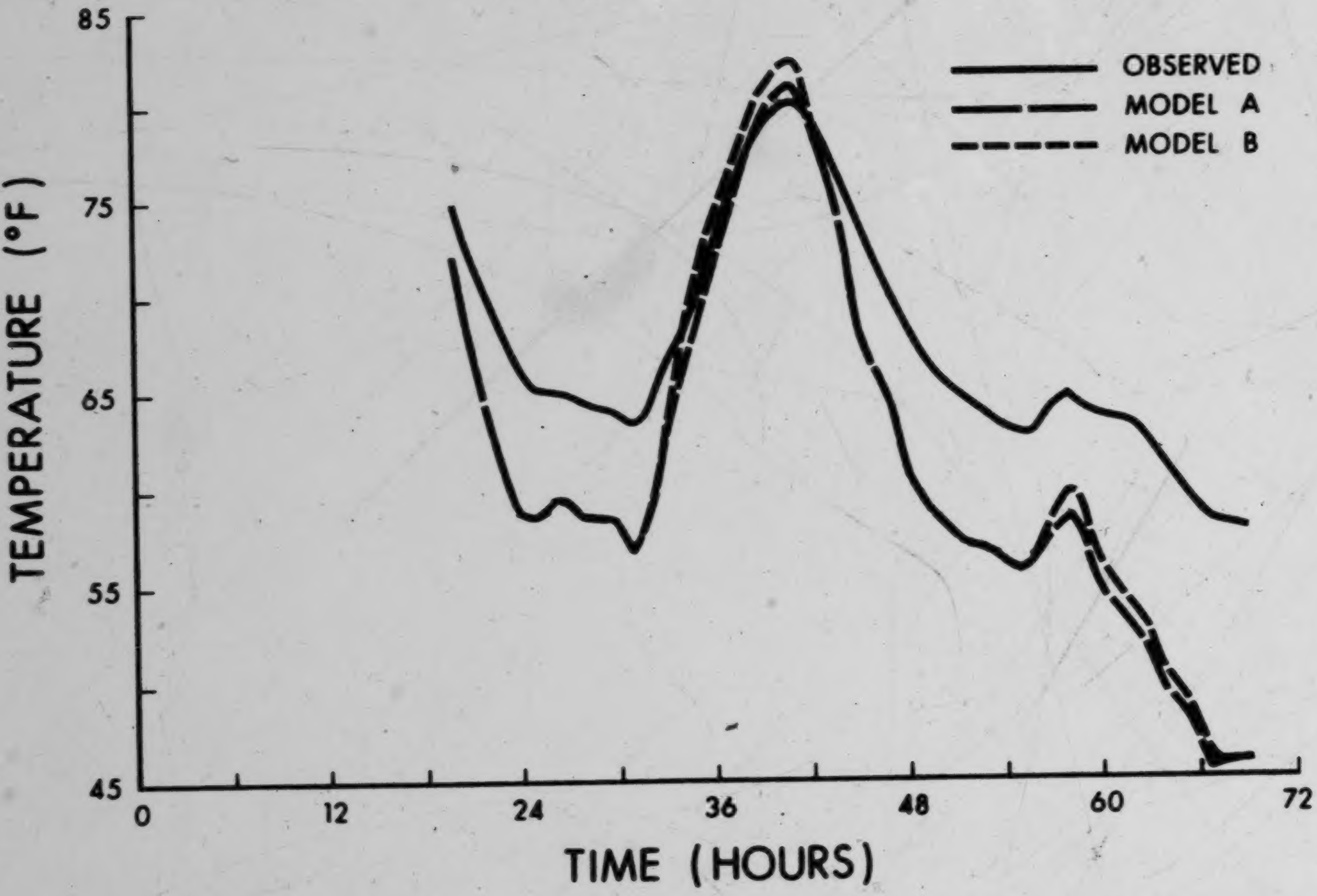


Figure 24: East wall inside surface temperatures.

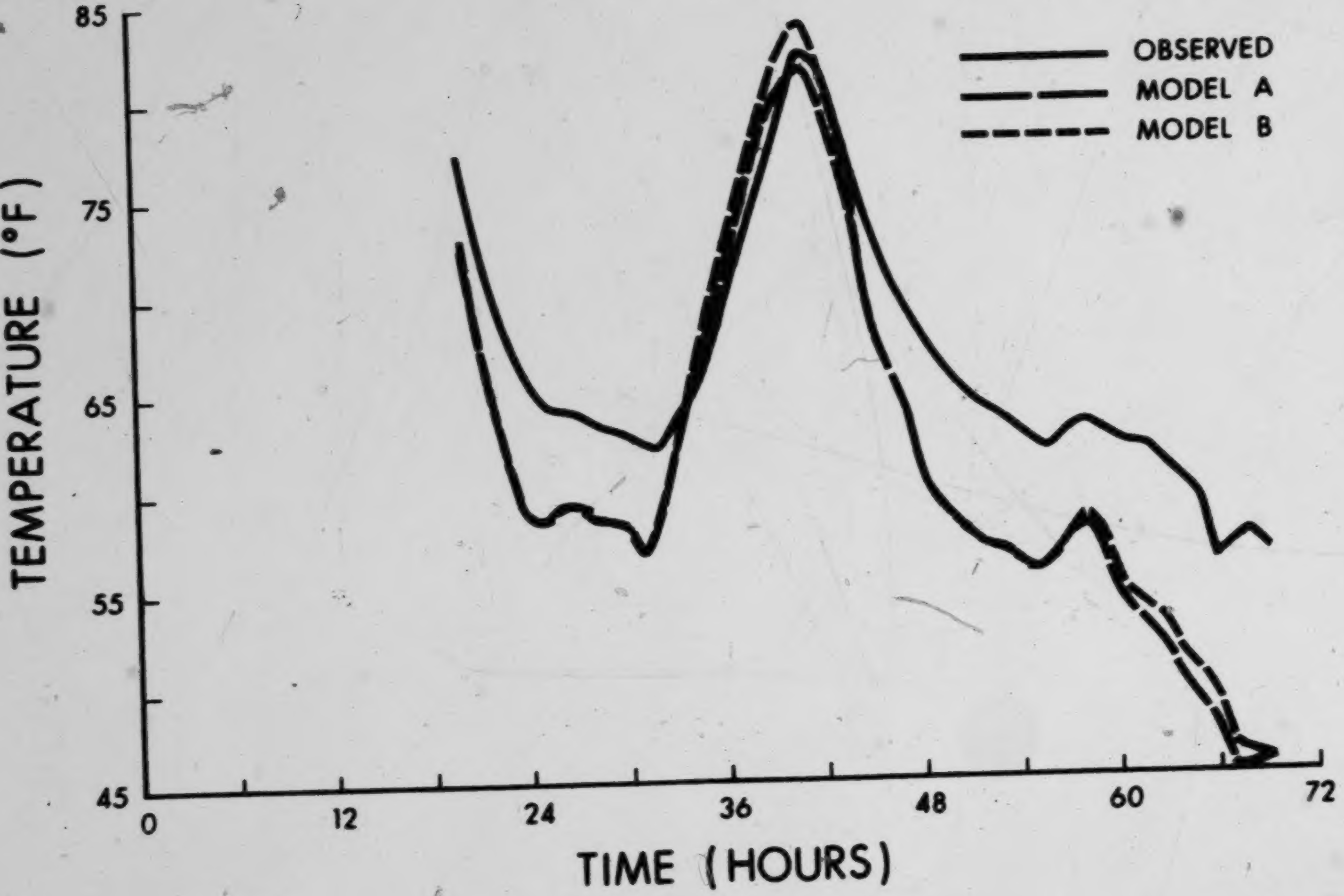


Figure 25: West wall inside surface temperatures.

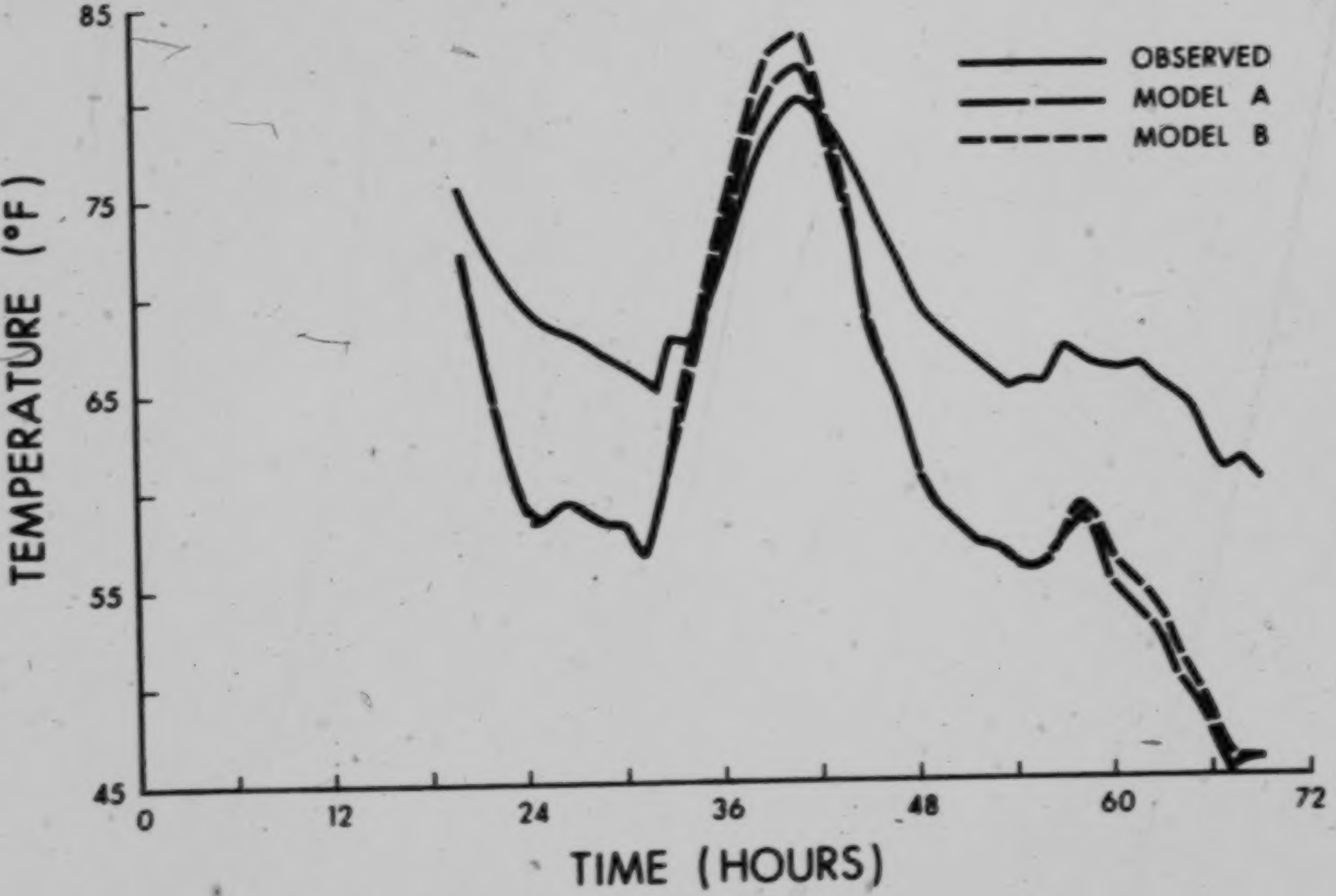


Figure 26: Ceiling inside surface temperatures.

Model A and Model B inside surface temperatures also are presented in Appendix G. The values for t, the correlation coefficient, the mean differences and the range of the differences for these temperatures are presented in Table 1.

Table 1 indicates that the observed and the model inside surface temperatures kept step in step very well, indicating that the model predicted the dynamic nature with a high degree of significance ($P<0.01$). The value for t, however, indicates that the hypothesis that the difference between the means of the predicted and observed populations was equal to zero could be rejected at the 99% level of confidence.

Figures 22 to 26 indicate that the inside surface temperatures, as predicted by both models was low generally when the inside dry-bulb temperature was predicted lower than that observed. During zero solar load (no solar radiation), both Model A and B predicted the same inside surface temperature. Generally, the residuals between the predicted and the observed inside surface temperatures were greatest during zero solar radiation and during periods of precipitation. Furthermore, the inside surface temperature prediction by Model B appeared to be more accurate than that by Model A (as indicated by the value for t) except for periods of high solar heat load on the outer surfaces (no precipitation and minimal cloud cover).

7.1.3.4 Outside Surface Temperature.

The observed and predicted values for the outside surface temperatures, as presented in Appendix G, are presented in Figures 27 to 32. The statistical data for observed versus Model A and B are presented in Table 2.

Table 2 indicates that Model A predicted the outside surface

TABLE 1. STATISTICAL ANALYSIS OF INSIDE SURFACE TEMPERATURES.

Model A Versus Observed

Statistic	South Wall	North Wall	East Wall	West Wall	Ceiling
correlation coefficient	0.97	0.95	0.98	0.96	0.96
t-value	-8.98	-5.69	-11.59	-10.30	-10.79
mean difference (predicted-observed)	-5.1°F	-3.6°F	-6.1°F	-5.3°F	-7.6°F
range of differences (predicted-observed)	-12.7 to 1.6°F	-11.2 to 4.7°F	-12.9 to 0.9°F	-11.8 to 2.1°F	-15.5 to 2.1°F

Model B Versus Observed

Statistic	South Wall	North Wall	East Wall	West Wall	Ceiling
correlation coefficient	0.97	0.95	0.98	0.96	0.95
t-value	-6.89	-4.75	-9.53	-8.36	-9.29
mean difference (predicted-observed)	-4.4°F	-3.1°F	-5.5°F	-4.7°F	-7.0°F
range of differences (predicted-observed)	-12.1 to 4.3°F	-11.2 to 6.1°F	-12.4 to 2.0°F	-11.3 to 3.9°F	-15.2 to 4.1°F

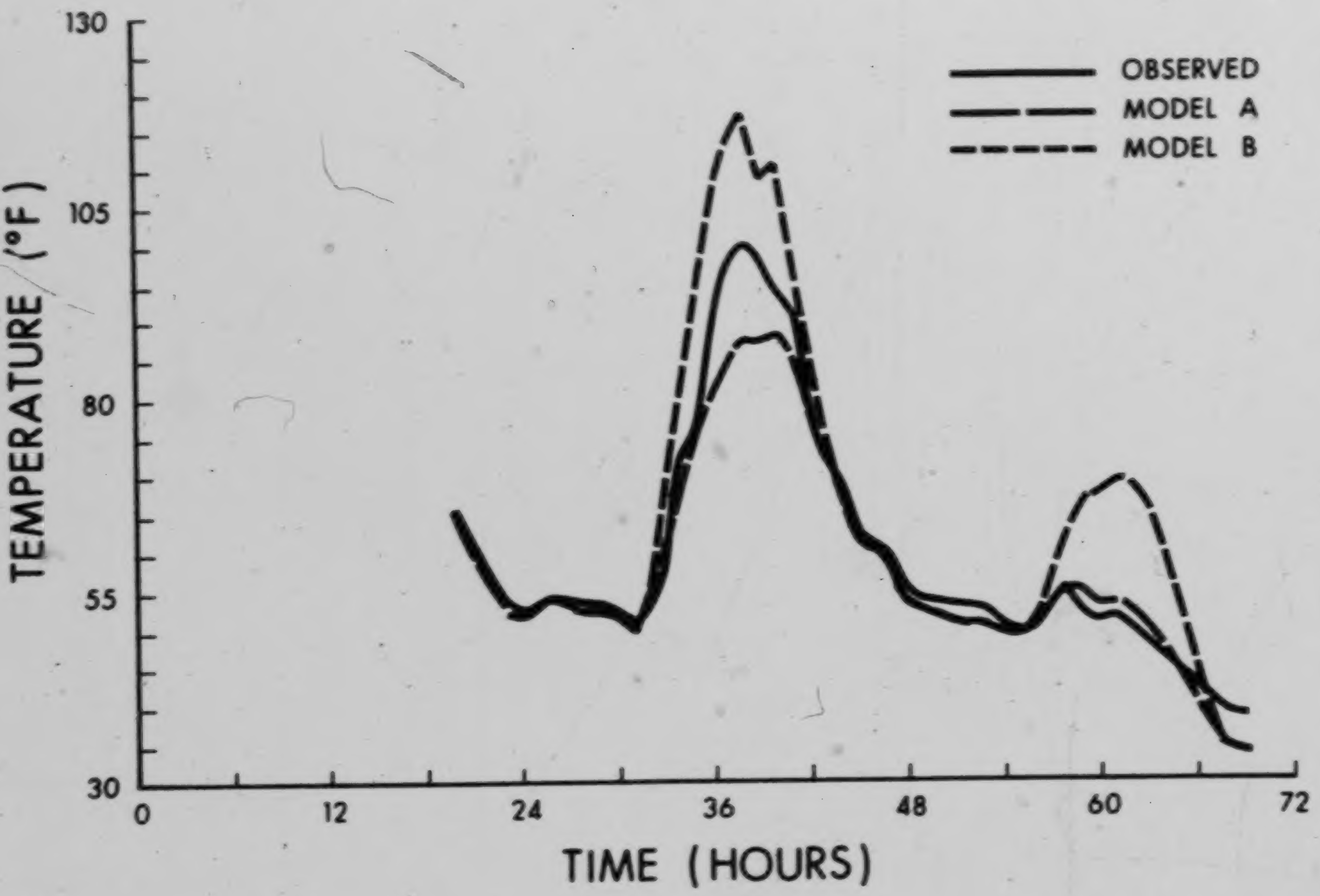


Figure 27: South wall outside surface temperatures.

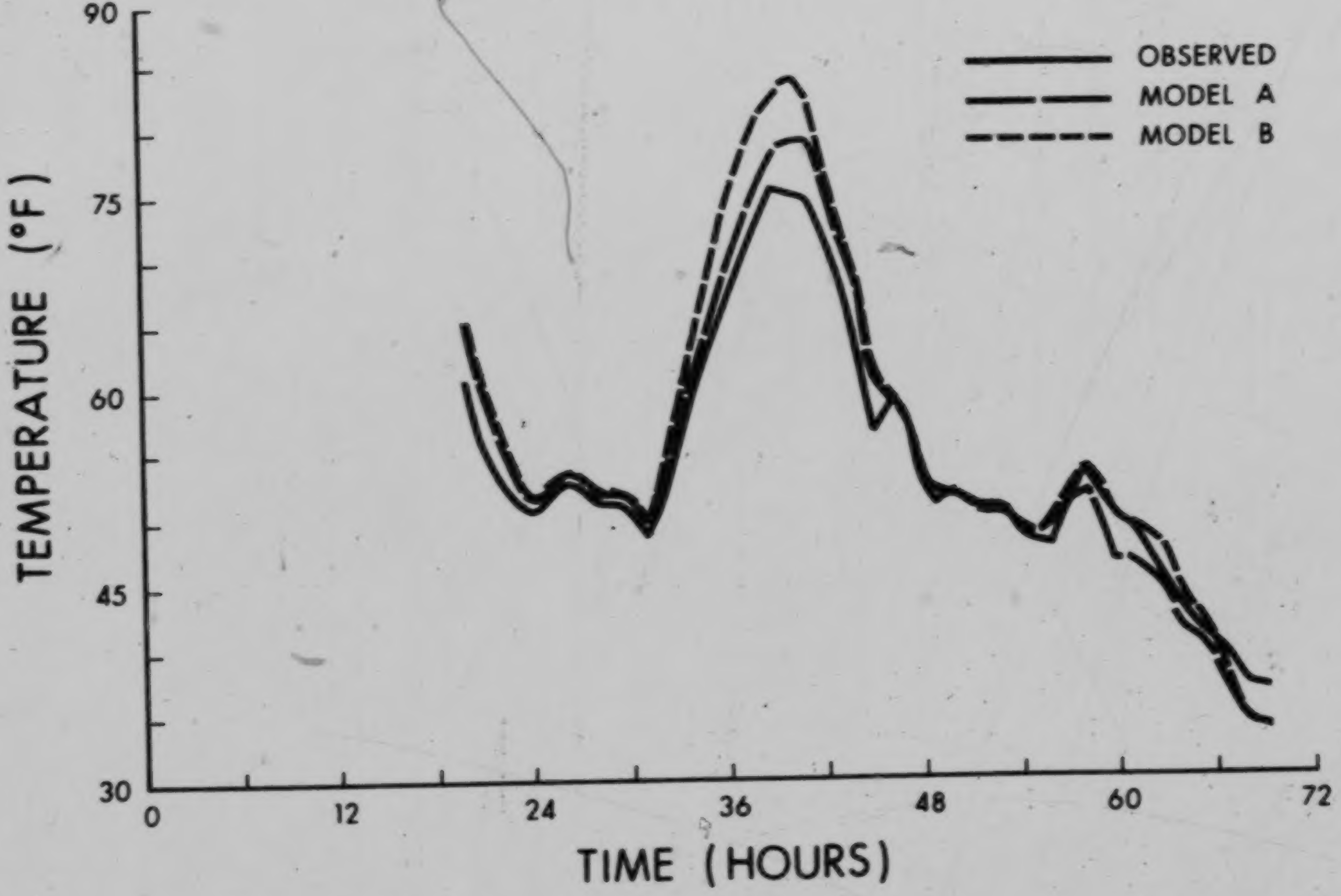


Figure 28: North wall outside surface temperatures.

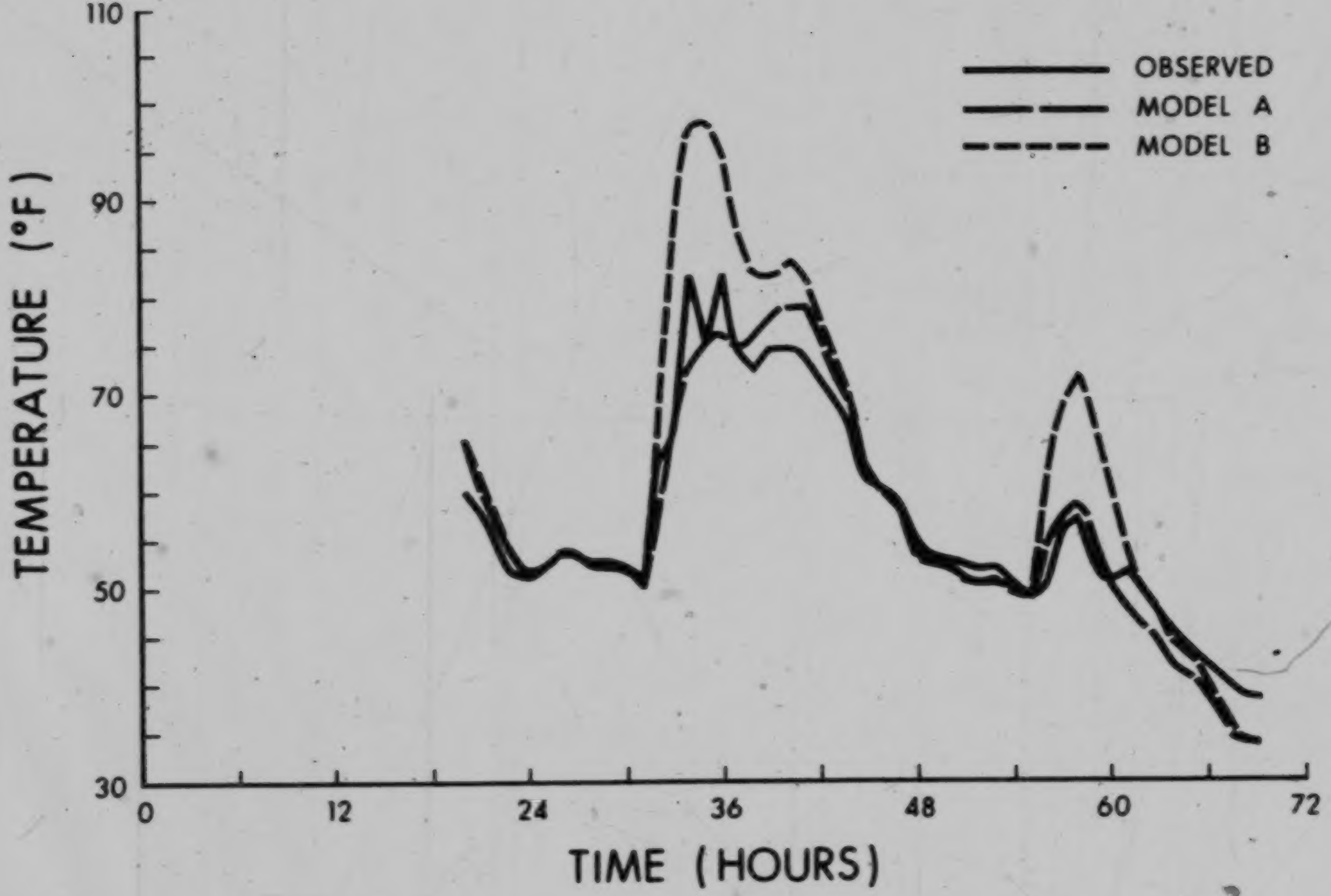


Figure 29: East wall outside surface temperatures.

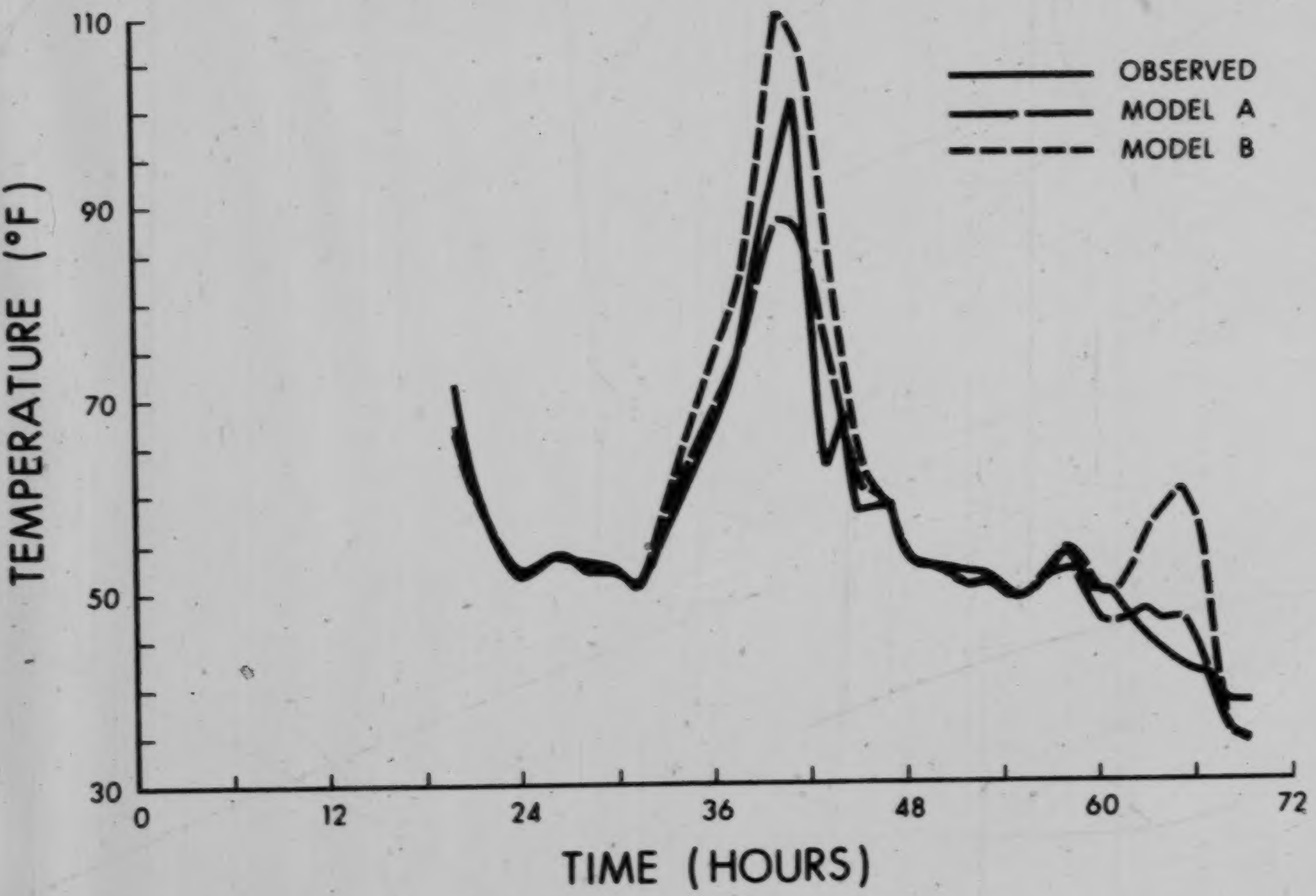


Figure 30: West wall outside surface temperatures.

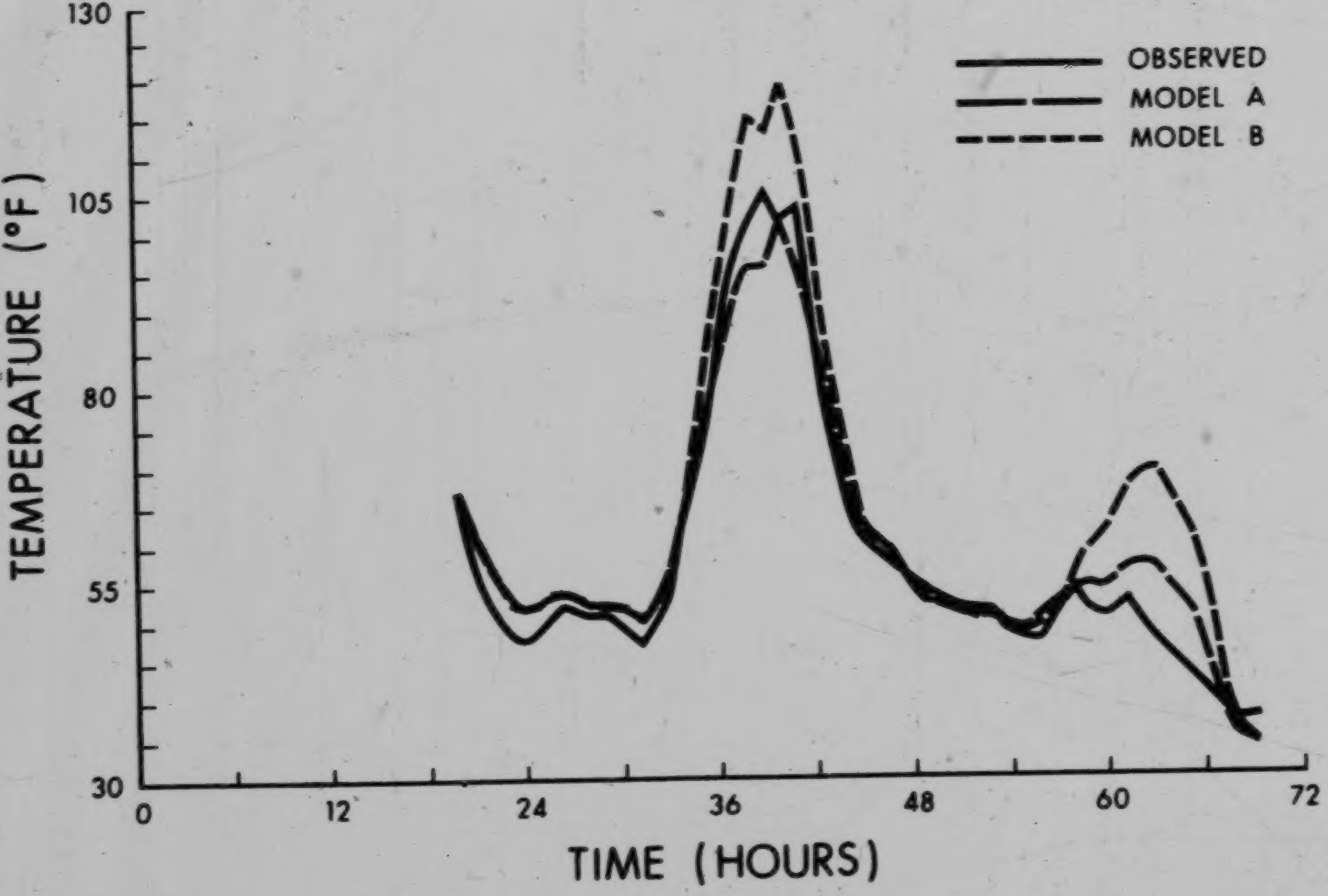


Figure 31: West slope outside roof surface temperatures.

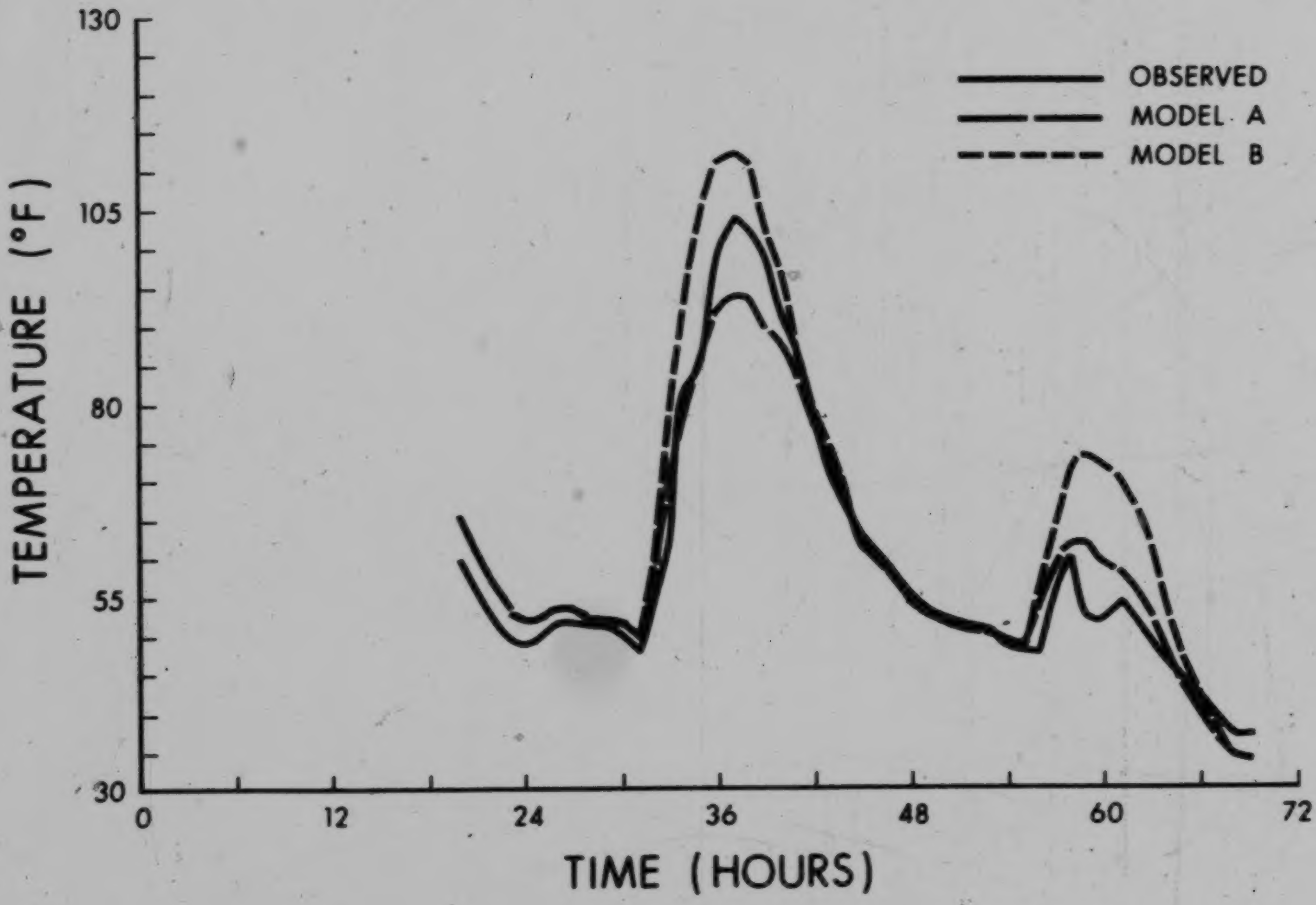


Figure 32: East slope outside roof surface temperatures.

TABLE 2. STATISTICAL ANALYSIS OF OUTSIDE SURFACE TEMPERATURES.

Model A Versus Observed

Statistic	South Wall	North Wall	East Wall	West Wall	East Slope Roof	West Slope Roof
correlation coefficient	0.98	0.99	0.97	0.97	0.98	0.98
t-value	-3.66	2.60	-0.87	-0.76	0.94	2.02
mean difference (predicted-observed)	-1.8°F	0.8°F	-0.4°F	-0.4°F	0.5°F	1.1°F
range of differences (predicted-observed)	-12.7 to 3.1°F	-3.3 to 4.5°F	-9.1 to 5.5°F	-12.9 to 13.2°F	-10.2 to 9.4°F	-9.6 to 9.6°F

Model B Versus Observed

Statistic	South Wall	North Wall	East Wall	West Wall	East Slope Roof	West Slope Roof
correlation coefficient	0.95	0.99	0.95	0.93	0.95	0.95
t-value	4.08	5.26	3.87	3.78	5.26	5.70
mean difference (predicted-observed)	4.3°F	2.2°F	3.7°F	3.4°F	4.8°F	5.2°F
range of differences (predicted-observed)	-4.9 to 20.6°F	-3.0 to 8.9°F	-4.8 to 24.4°F	-4.7 to 22.2°F	-3.2 to 21.0°F	-3.4 to 21.8°F

temperature with a higher statistically significant degree of accuracy. The correlation for both models is very highly significant. The value for t indicates that Model A predicted the outside surface temperature for all outside surfaces, except the south wall, with a highly significant degree of accuracy. The hypothesis that the difference between the mean of the observed population and the mean of the predicted population was zero could not be rejected at the 99% confidence level. Excluding the north and south wall, the hypothesis could not be rejected even with 95% confidence.

Inspection of the values for outside surface temperatures indicates that during the period of low heat load on the outer surface of the building (zero solar load) the model predicted the outside surface temperatures with a highly significant degree of accuracy. Furthermore, using outside temperature to represent the outside conditions gave a high degree of accuracy for predicting outer surface temperature, especially during minimal heat load periods. However, during periods where the solar heat load on the outer surfaces was high, the prediction using outside temperature to represent outside conditions was low, while the prediction using sol-air temperature to represent outside conditions was high. This may indicate that the algorithms to calculate heat transfer in the model should be altered to accurately use sol-air temperature.

7.1.3.5 Summary.

The foregoing discussion noted that predictions of inside conditions and surface conditions were of the same order, that is, when one prediction was too low the other was as well. This was due to the very dynamic and interactive dependence of surface temperature on inside and outside conditions and vice versa.

No association could be developed between predicted values for inside relative humidity and predicted values for inside dry-bulb temperature nor could these values be associated with changing conditions as noted by Phillips and Esmay (85). In their verification trials using a model to predict the environment in poultry-production units, they found that maximum deviations occurred when outside or inside conditions were changing rapidly. In these situations, their model tended to respond instantaneously while actual conditions were buffered by physiological or structural effects. They also found that higher than actual temperature predictions were associated with low humidity predictions and vice versa. They concluded that this tended to indicate that the surface temperature of deep litter, which has a major influence on evaporation, was in fact responding more rapidly than predicted.

Using the sol-air temperature to represent the outside conditions resulted in a more accurate prediction of inside surface temperature and inside ambient conditions, whereas using the outside temperature to represent the outside conditions resulted in a more accurate prediction of outside surface temperatures. These results indicate the need to check and possibly alter the algorithms associated with the determination of surface temperature and heat flux so that sol-air temperature might be accurately used. These changes should give the same or similar results as when using the outside temperature with the present model which includes radiation and convection at the outer surface in calculation of heat flux and surface temperature.

The results of this verification may have been in error due to the wet conditions and the related error in the theoretical model as mentioned previously. Furthermore, the mechanical failure of the chopper on the temperature recorder may have introduced error in the observed readings prior to the time when error was detected and the verification trial halted.

Error in inside temperature prediction also may have resulted from data errors in heat and moisture production of swine. A relative humidity of 50% was used to derive the regression equations used to predict heat and moisture production of the animals (16). High relative humidity tends to decrease evaporation, thereby altering the sensible and latent heat production as predicted by the regression equations in the model.

There are numerous other areas where the model may be in error due to inaccurate data. For example, thermal conductivity varies with many factors of which the specific gravity and moisture content and its distribution are the most important (99). The magnitude of error associated with these sources are much too dynamic and interactive to determine.

The general agreement of some of the results of this verification with others can be noted. Good (42) developed a model to simulate environmental control and found inside temperature and relative humidity prediction to generally agree with the observed, but rejected the hypothesis that actual and predicted data were from the same population. Wilson (103) found that the simulator using finite differences to model transient heat transfer was a good predictor during daylight hours but not during the night.

7.1.4 Heat Transfer.

The program output (Appendix J) gives the hourly heat flows through the structural components. These are given for the walls, doors, floor, horizontal roof, pitched roof and windows. The summation of these then are entered under total heat transfer.

All values under the horizontal roof are zero since the area for the horizontal roof is zero (no horizontal roof). This indicates that the solar calculations and surface temperatures for the horizontal roof were not included in calculations of heat load due to heat transfer through the horizontal roof. These values are given in British Thermal Units per hour with positive values indicating heat transfer into the total confinement and negative values indicating heat transfer out of the unit. A positive heat load on the building occurs during periods of relatively high solar heat load on the building, otherwise a heat loss through the structural components occurs.

The heat transfer through the doors, as predicted by the model,are fairly large negative values. These may be incorrect due to an error in the manner in which values are assigned to the common block (common area in the computer which is accessible to all program segments) within the model. Time and financial restrictions prevented the author from modifying the computer program so as to remove this imperfection. Such imperfections and limitations can only be removed after considerably more experience with the model.

7.1.5 Ventilation Criteria.

The computer model printed the hourly ventilation criteria as calculated for the model hog barn as presented in Appendix J. The variables included are as mentioned previously.

The ventilation within the facility was constant at 3000 cfm; i.e., the ventilation rate determined for the building. The ventilation rate required to remove the resultant heat load was calculated within ± 3 percent of the ventilation rate within the building as specified. The relative humidity at this ventilation rate also was printed. The ventilation rate required to remove moisture to maintain an optimal relative humidity of 70% also was calculated as well as the supplemental heat requirement. The supplemental heat requirement was negative when the ventilation rate required to remove moisture load was lower than that to remove the heat load, indicating the need for cooling. This may be achieved by sprinkling, spraying, refrigerating, etc. (18,29,48,54,78). The negative values indicate the cooling requirement in British Thermal Units of heat per hour.

7.2 Sensitivity Analysis.

Since sensitivity testing is an essential part of the validation process, certain input parameters were tested to determine their impact on the model prediction. The inside temperature was chosen to be the most important criterion for sensitivity analysis and was used as a measure of effectiveness.

7.2.1 Incoming Temperature.

The initial validation assumed the incoming temperature as that of the outside air. Since the air used for ventilation purposes was drawn through the attic space, this was not an accurate assumption. A.S.H.R.A.E. (4) give a general relationship for estimation of attic temperature which neglects the effects of any interchange of air such as would take place through attic vents or louvers intended to preclude attic condensation under natural ventilation. The same reference source indicates that test data have determined that the reduction in temperature difference between attic air and weather is linear with mechanical ventilation rates between 0.0 and 0.5 cubic feet per square foot of ceiling area. The relationships for determining attic temperature do not consider such factors as heat exchange within the attic, solar radiation, naturally ventilated conditions and conditions where air is drawn through this naturally ventilated attic space as existed within the test facility. For these reasons, an approximation method for determining attic temperature was not used and the attic temperatures were monitored. These temperatures were then assumed as the ingoing or ventilating air temperatures.

The resulting inside dry-bulb temperature, as presented in Appendix G, is plotted in Figure 33 along with the observed and that determined using the outside temperatures as the incoming temperature (Model B used for comparison).

As noted previously, the correlation coefficient for Model B and the observed was 0.97 with a value for t of -12.55 and a mean difference of -7.9°F (range -15.9 to 0.3°F). Using the attic temperature to represent the incoming temperature, the resulting correlation with the observed was 0.98. The value for t was -4.88 and the mean difference was -3.1°F (range -8.6 to 7.4°F). The result was a slightly better correlation and a much more highly significant value for t. The difference between the means also was reduced substantially.

Figure 33 indicates the improvement in inside dry-bulb temperature prediction that occurred during periods of under-estimation by the model when the ingoing temperature was assumed as that of the outside air. However, during the period when the inside temperature prediction was accurate using outside temperature to represent incoming temperature, the prediction using the attic temperature to represent incoming

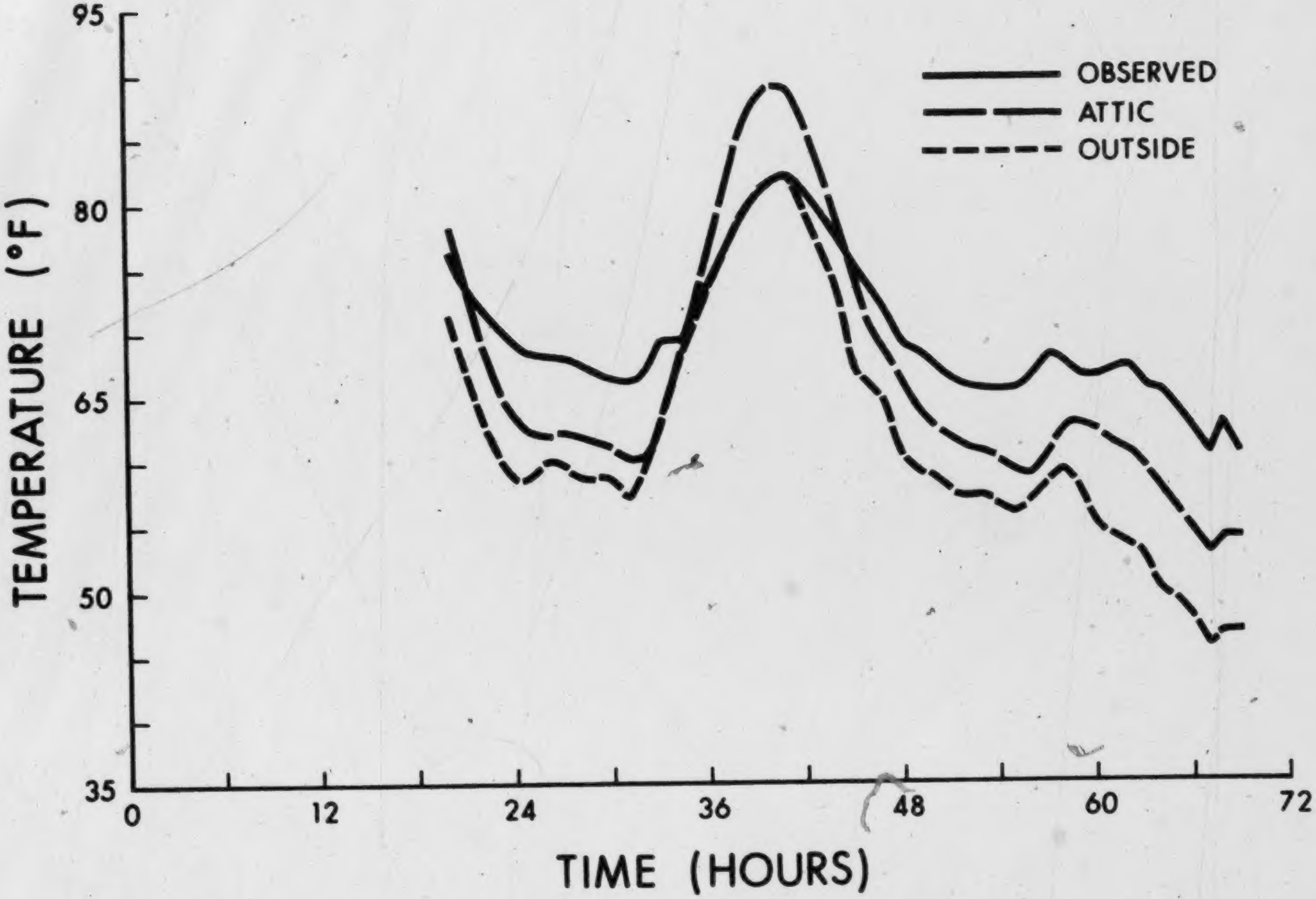


Figure 33: The effect on inside room dry-bulb temperatures of changing the ingoing air temperatures from that of the outside air to that of the attic space.

temperature was much too high.

These results indicate that attic temperatures must be considered for estimating the incoming temperature, but under naturally ventilated conditions these are difficult to determine. In addition, the ingoing (incoming) air may be some combination of the outside air and attic air depending on such weather factors as wind speed, wind direction and barometric pressure as well as the location and area of air vents and/or louvers into the attic and from the attic to the room.

7.2.2 Heat and Moisture Production.

The heat and moisture production of the confined animals are the major constituents of the resultant heat and moisture load on the building. As the test facility was a swine confinement unit, the heat and moisture production for swine was determined by regression equations (16) as recommended for design purposes (2,4,36).

Bluffington et al (13) noted that estimates of heat and moisture lost by livestock and poultry inside a building are probably the least reliable of all the factors contributing to the temperature and humidity conditions inside a building.

Reece and Deaton (87) studied the latent and sensible heat production of a poultry barn on a whole-house basis and found important diurnal variations. Their results indicated that there are a number of factors that are beyond control that must be considered to predict the exact heat and moisture production rates of confined animals or birds.

The continuous changes in heat loss for purposes of design cannot be accurately defined. Consideration should be made to simulate the greater heat loss after feeding as noted by Bond et al (15) as well as the affect of animal movement on heat loss by convection as noted by the same authors. Interesting results with beef cattle in total confinement buildings also were noted by Remmele et al (88). They found that latent heat production from such a unit decreased as relative humidity and animal density increased, but increased with increasing temperature. Sensible heat production also was found to decrease as temperature increased but to increase as relative humidity increased.

Hahn (47) indicated that studies in Germany had confirmed the accuracy of the data of Bond et al (16). This led to further attempts by the author to establish the validity of these data from several foreign sources under varying climatic and management systems with regard to heat and moisture data in confinement buildings (7,10,46,92, 105). Baxter (10) provided some original data from work conducted at the Farm Buildings Institute in Holland that appeared to agree with the data used, but these were not sufficiently extensive to make an absolute statement on the level of agreement. Further communications with this Institute (46) did not prove fruitful.

The Max-Planck Institut (105) provided some information regarding heat and moisture production in all livestock buildings. This work (106) was undertaken to find if the latest German legal code was valid. The German Industry Code which constitutes the legal codes in Germany has been continuously updated. Only a 1963 translation (31) of the code could be obtained.

Wolfermann and Hornig (106) noted that exact data for heat and moisture production of animals over time were of utmost importance for the calculation of heat balance and ventilation within modern confinement units and stated that data relating to new housing systems for livestock are non-existent. They also noted that work in the U.S.S.R.

shows considerably different results than those by Bond et al (16). Their own studies with regard to heat and moisture production resulted in the following:

1. There were no significant differences between day and night heat and moisture production in a piggery with feeder pigs and no bedding on partly slatted floors (liquid manure systems), but moisture dissipation data were significantly higher than data used up to the present.
2. A lower water-vapor output occurred at night than during the day, with the heat output being higher during the day than at night, in a piggery for breeding purposes without bedding, slatted floor or liquid manure system:.

They concluded that moisture and heat dissipation with regard to new housing systems are considerably higher than expected.

Considering all the foregoing, the sensible heat production and the moisture production were increased and decreased by 20% to give all the possible combinations of these effects. The resulting inside dry-bulb temperature is presented in Figures 34 to 36. (as well as Appendix G). The statistical analysis of these are presented in Table 3.

This analysis indicated that decreased moisture production and increased sensible heat production significantly improved the accuracy of prediction of inside dry-bulb temperature. This indicated that accurate heat and moisture production data for the animals confined was very important. These data may vary substantially due to variation in the species confined, ration fed, thermal stress, housing systems used, etc.

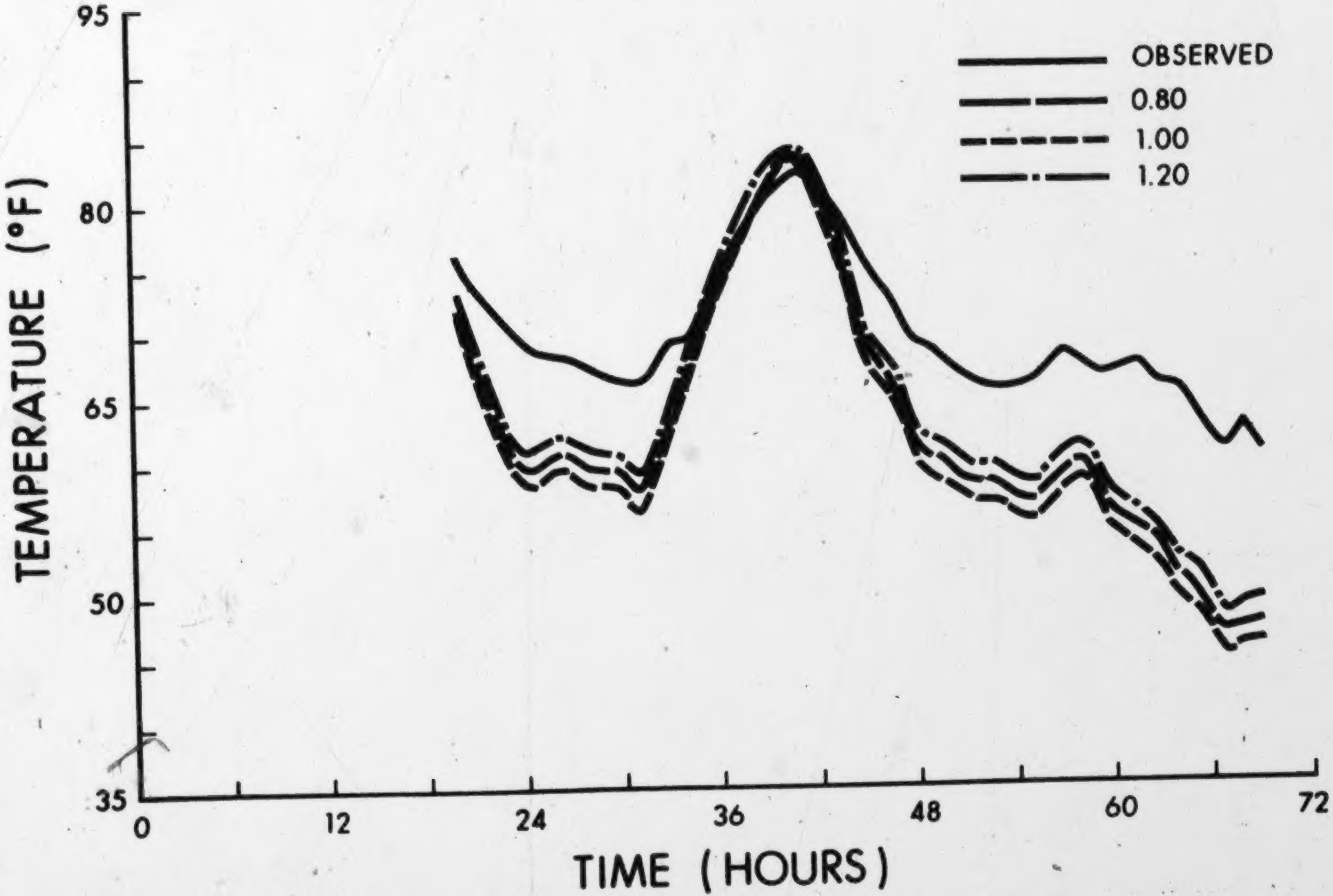


Figure 34: The effect on inside room dry-bulb temperatures of varying the management factor for sensible heat production and maintaining the management factor for moisture production at 0.80.

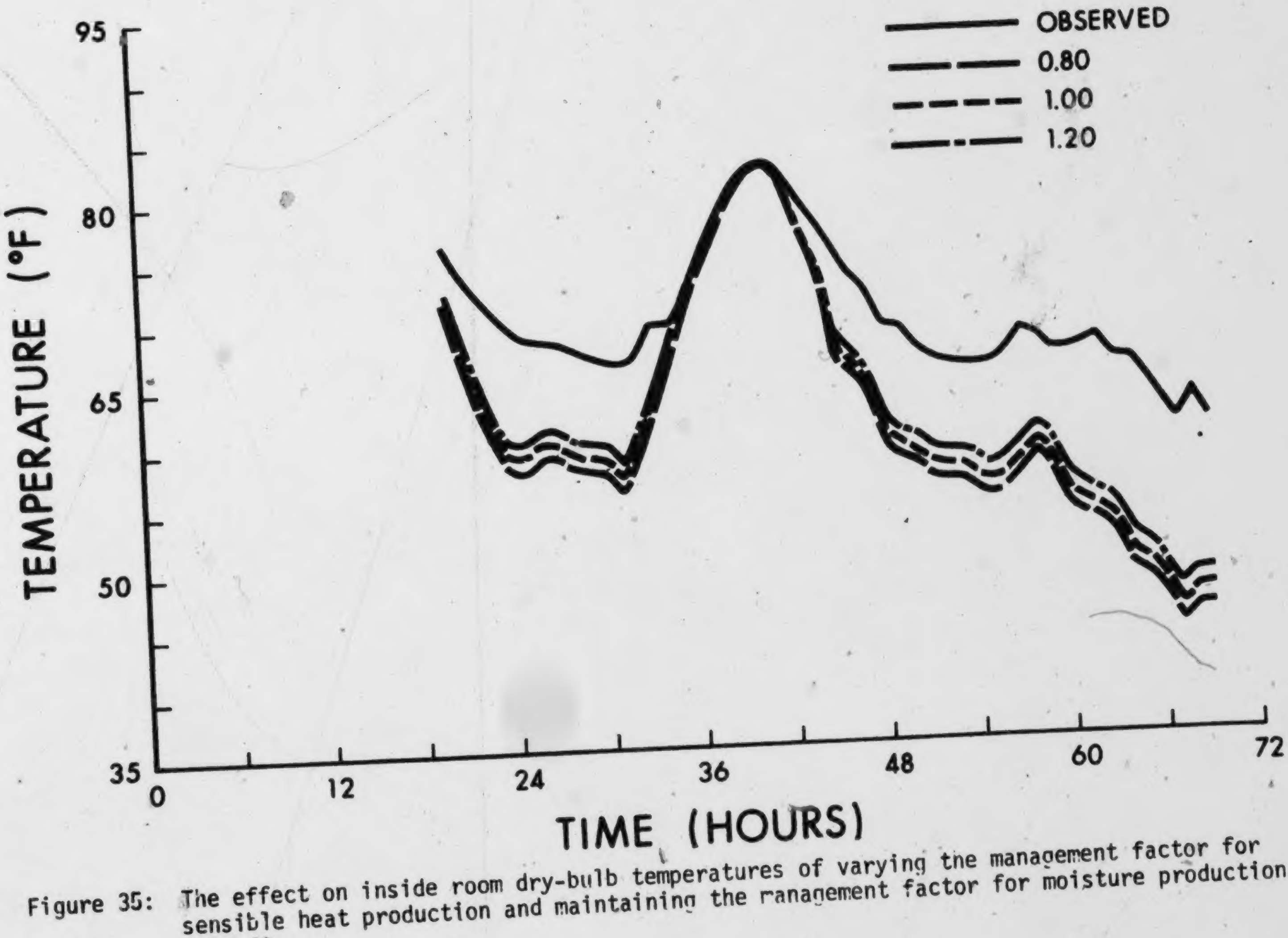


Figure 35: The effect on inside room dry-bulb temperatures of varying the management factor for sensible heat production and maintaining the management factor for moisture production at 1.00.

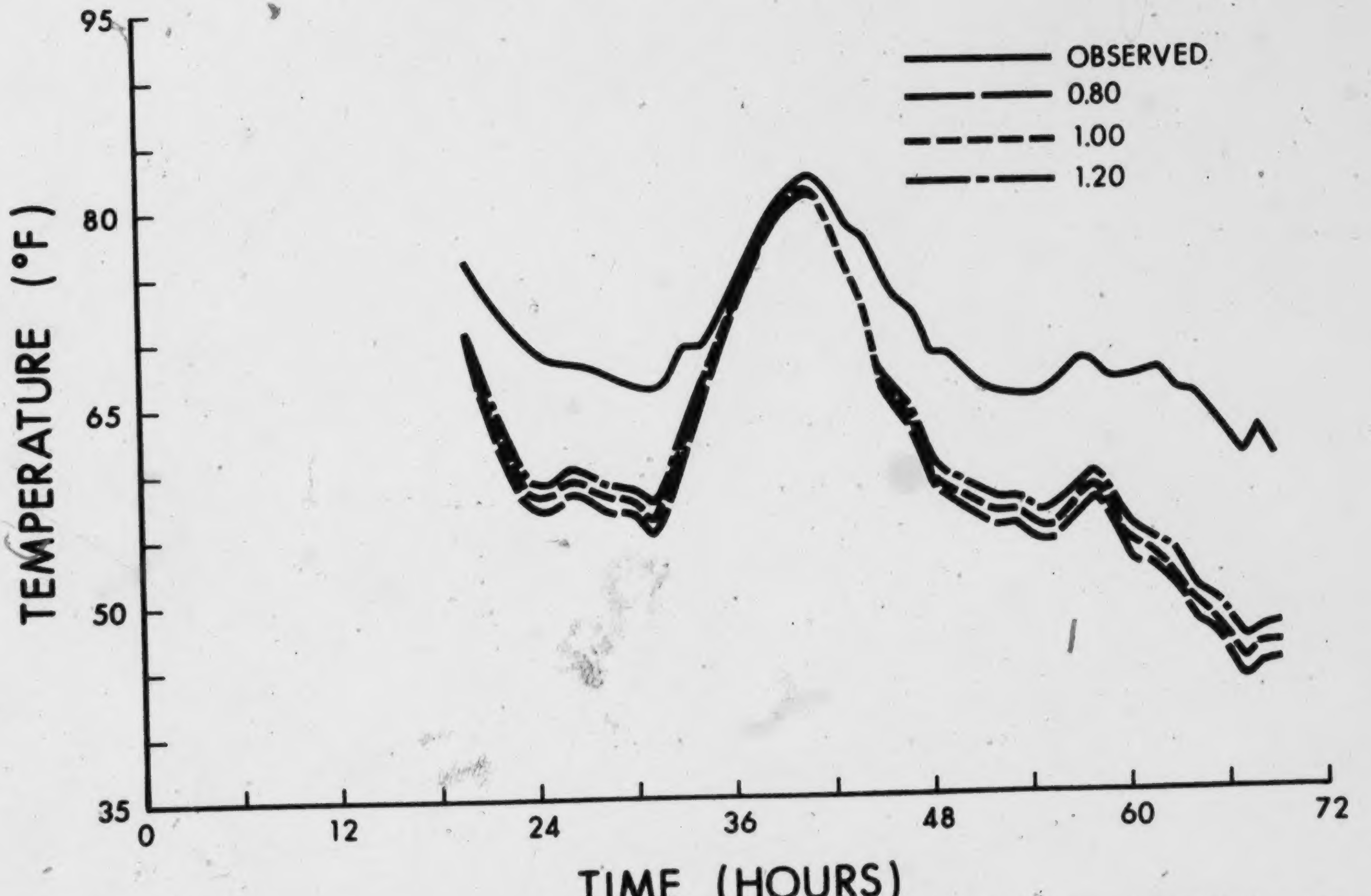


Figure 36: The effect on inside room dry-bulb temperatures of varying the management factor for sensible heat production and maintaining the management factor for moisture production at 1.20.

TABLE 3. STATISTICAL ANALYSIS OF INSIDE DRY-BULB TEMPERATURE RESULTING FROM SENSITIVITY ANALYSIS ON HEAT AND MOISTURE PRODUCTION. (Observed versus Predicted).

management factors used in the model	correlation coefficient	t value	mean difference (predicted-observed)	range of differences (predicted-observed)
moisture 0.8 sensible heat 0.8	0.97	-12.22	-8.4 °F	-16.9 to 0.7 °F
moisture 0.8 sensible heat 1.0	0.97	-10.74	-7.0 °F	-15.3 to 1.5 °F
moisture 0.8 sensible heat 1.2	0.97	- 9.44	-5.8 °F	-13.7 to 2.2 °F
moisture 1.0 sensible heat 0.8	0.97	-13.55	-9.1 °F	-17.5 to 0.2 °F
moisture 1.0 sensible heat 1.0	0.97	-12.55	-7.9 °F	-15.4 to 0.3 °F
moisture 1.0 sensible heat 1.2	0.97	-11.33	-6.8 °F	-14.5 to 0.8 °F
moisture 1.2 sensible heat 0.8	0.97	-14.96	-9.7 °F	-18.0 to-1.2 °F
moisture 1.2 sensible heat 1.0	0.97	-14.34	-8.8 °F	-16.6 to 0.9 °F
moisture 1.2 sensible heat 1.2	0.97	-13.61	-7.8 °F	-15.2 to 0.3 °F

7.2.3 Other Parameters.

The sensitivity of the model to several additional parameters was carried out, including;

1. increasing emissivity factor of the outside wall surface from 0.92 to 0.95,
2. decreasing emissivity factor of the outside wall surface from 0.92 to 0.85,
3. increasing absorptivity factor of the outside wall surface from 0.40 to 0.50,
4. decreasing absorptivity factor of the outside wall surface from 0.40 to 0.25,
5. increasing emissivity factor of the outside roof surface from 0.93 to 0.95,
6. decreasing emissivity factor of the outside roof surface from 0.93 to 0.85,
7. increasing absorptivity factor of the outside roof surface from 0.82 to 0.91,
8. decreasing absorptivity factor of the outside roof surface from 0.82 to 0.78,
9. increasing the overall heat transfer coefficient for the windows from 0.66 to 0.80,
10. decreasing the overall heat transfer coefficient for the windows from 0.66 to 0.50,
11. averaging all the hogs into one average weight of 75 pounds,
12. decreasing the inward-flowing fraction of radiation for the inner and outer pane from 0.67 and 0.17 to 0.50 and 0.12 respectively,

13. increasing the inward-flowing fraction of radiation for the inner and outer pane from 0.67 and 0.17 to 0.85 and 0.23 respectively,
14. increasing clearness number from 1.0 to 1.1,
15. decreasing clearness number from 1.0 to 0.8,
16. decreasing the thickness of the insulation from 2.0 to 1.5 inches for the walls and ceiling,
17. increasing the thickness of the insulation from 2.0 to 2.5 inches for the walls and ceiling,
18. increasing the inside air film conductance coefficient from 1.46 to 3.0,
19. decreasing the inside air film conductance coefficient from 1.46 to 1.3,
20. decreasing outside air film conductance coefficient from 4.0 to 2.0, and
21. increasing outside air film conductance coefficient from 4.0 to 6.0.

These values were chosen on the basis of previously mentioned deviations found in the literature.

These individual variations resulted in a maximum of $\pm 1.5^{\circ}$F change in the inside dry-bulb temperature with an average change of $\pm 0.5^{\circ}$F. Due to the very large amount of data acquired, these are not presented. In addition to analyzing the sensitivity of each of these variables on the inside dry-bulb temperature, a statistical analysis was carried out for each of the surface temperatures as well as the inside relative humidity. The results were in the same order as those indicated by the inside dry-bulb temperature. This agreement shows that the values chosen for these properties do not have a great effect on the accuracy by which the model predicts the thermal environment. However, the additive effects of several of these changes may be very significant. Furthermore, the effect of these changes under completely different conditions also may be significant.

8. SUMMARY AND CONCLUSIONS

The model of the thermal environment within total confinement livestock housing developed in this project achieves the accuracy, flexibility and adaptability necessary for systems analysis of environmental control alternatives in total confinement. This model is an effective tool for studies concerned with the dynamic behavior of the thermal environment in such units. The algorithms included in the model give the accuracy and sophistication required to simulate the dynamic thermal environment that exists in commercial livestock housing. The model also provides the desired flexibility for incorporation of future developments as they may arise. The detailed documentation should assist interested persons to use the model with no serious difficulties.

The validation of the model indicates that the model cycles and effectively predicts the dynamic nature of the thermal environment within total confinement. However, the predictions are very sensitive to the accuracy of input parameters. As Hinkle (55) stated "... the output from the computer is no better than the data and information going in."

The predictions of the dynamic behavior of the real system by models depends largely upon the accuracy of the assumptions concerning the basic characteristics of the real system. This model, having the advantages of the digital computer with its enormous memory capacity, accuracy and speed, make it possible to handle the very complex dynamic behavior of the environmental system. However, to realize the full potential of a dynamic simulation such as this, the assumptions listed earlier must be replaced with more valid time dependent data.

Environmental control involves requirements arising from the physiology, nutrition, reproduction and behavior of animals and the provisions of physical facilities and systems of management so that production may be organized efficiently. As many different factors are interacting in the situation, no simple universal solutions are to be expected.

9. SUGGESTIONS AND PRACTICAL IMPLICATIONS

Experience with and modifications to the model are required to define and evaluate any imperfections and limitations that may exist within the model. Of utmost importance, this model must be validated with more data in several locations, including very warm (summer) and very cold (winter) conditions. These verification trials should apply a data aquisition system for collection and reduction of experimental data. Not only the similarities between the model and the real system should be examined, but also the differences between the specific properties of the model and real system. Investigation such as this may reveal unexpected properties of the model to correct imperfections in theory.

To achieve maximum accuracy, there are a number of areas which require further research or action to replace assumptions with actual data and relationships. Experience with the model has indicated that such data include: heat and moisture production of animals as they are affected by varying conditions; condition of the incoming air used to ventilate the building; effects of varying wind conditions; heat sources and sinks such as furnishings, occupants and equipment in the room; effects of age, moisture, etc. on the range for thermal coefficients; and effect of infiltration.

The replacement of these parameters with actual data as well as replacement of all assumptions cited earlier within the main body of this study with actual data, will result in a much more realistic simulation model. Of greatest importance is the heat and moisture production and condition of the incoming air drawn through the attic space as indicated by the sensitivity analysis. This is especially important as most swine in Alberta are reared in confinement and approximately 40% of these units are ventilated through the attic in summer and 90% are ventilated in this manner in the winter (27).

Consideration should be given to such variations as may occur in conductances through the attic air space with time as noted by Wilson (103). Results, such as those noted by Kimura and Stephanson (62) which show that the solar intensity on a partly cloudy day can be higher than on a completely cloudless day suggesting that the values may be higher than the values indicated by the A.S.H.R.A.E. formulas used in this model, should be investigated to assess their impact.

There are certain models and algorithms which may be adapted and used to possibly improve upon this model. These may include:

1. A model proposed by Beckett and Vidrine (11) to predict the heat produced, moisture produced, pig surface temperature and rate of weight gain. A model such as this, however, requires vast amounts of accurate data which would not necessarily improve the model, but may prove useful in predicting the rate of gain of hogs.
2. A model by Teter et al (98) for simulating the metabolic energy intake, heat loss and growth efficiency of broilers over a range of weights, temperature and metabolizable energy in the feed.
3. Algorithms by Carson (23) for use in optimizing economic returns and predicting performance of the animal within the confinement unit so as to provide swine producers with a quantitative set of precise design alternatives and the economic implications of these alternatives.

4. Equations recently derived by Morrison et al (79) to relate the combined effects of temperature and humidity on the rate of gain of hogs.
5. A model proposed by Bluffington et al (13) that simulates heat production of active growing Wrolstad white turkeys, based on experimental values of heat production obtained by indirect calorimetry and on growth data.
6. A model proposed by Paine and Butchbaker (83) for beef animals to predict the heat and moisture production under varying conditions.
7. A mathematical model by Butchbaker et al (21) to simulate beef animal performance (average daily gain and feed efficiency) in confinement buildings.
8. A model by Strombaugh and Roller (97) for modelling thermoregulatory control of piglets.

Many of these alternatives would be adapted for the systems design of confinement units other than swine units.

Furthermore, the model may be improved to include materials handling facilities, manure disposal and alternate feeding methods. Prices then may be attached to components, thus incorporating costs for evaluation of economic performance.

One of the major assets of a model such as this is its usefulness as a tool in the investigation of adjustable parameters which may affect the system. A series of simulations may be conducted to evaluate changes in design and management factors that might produce optimum design such as carried out by Phillips and Esmay (85). Variables that may be considered include location, orientation, materials, fan size, heater size and stocking density. Sensitivity of such factors as the effect of size, shape, color and orientation of buildings on interior thermal environmental conditions may be carried out to verify the experimental results of such findings on a small box basis with no inside heat sources (81,82).

Hopefully, the most valuable application of the model will be to serve as a stepping stone for future models that are more accurate and complete, and perhaps if used with other detailed models, it might serve as a component part of an overall model that would allow a detailed analysis of the total pork production system and perhaps even the total agricultural system.

Computer simulation programs such as this can be used to test one of the many parts of a total system easier, cheaper and infinitely quicker than could be done in an actual field experiment.

10. LITERATURE CITED

1. Albright, L.D. and N.R. Scott. 1973. Predicting steady-periodic variations of building temperature. Paper No. 73-408, Amer. Soc. of Agr. Eng., St. Joseph, Michigan 49085.

2. American Society of Agricultural Engineers. 1973. Agricultural Engineers Yearbook. Amer. Soc. Agr. Eng., St. Joseph, Michigan 49085.

3. American Society of Heating, Refrigerating and Air-Conditioning Engineers. 1971. Procedure for Determining Heating and Cooling Loads for Computerized Energy Calculations. A.S.H.R.A.E. Inc., New York.

4. American Society of Heating, Refrigerating and Air-Conditioning Engineers. 1972. Handbook of Fundamentals. A.S.H.R.A.E. Inc., New York.

5. Anderson, A.W. 1965. A study of the application of linear programming and the associated technique of decomposition for use on farm management problems in Alberta. Unpublished M.Sc. Thesis, Department of Agricultural Engineering, University of Alberta.

6. Anderson, A.W. and P.J. Barlott. 1973. A continuous simulation model of Western Canadian feedlot operations. Paper No. 73-204, Can. Soc. Agr. Eng., Suite 907, 151 Slater St., Ottawa, Ontario.

7. Arbeitsgeineinschaft Landwirtschaftliches Bauwesen e.V. (ALB). 1973. Personal communications. Frankfurt/Main, West Germany.

8. Associate Committee on the National Building Code. 1970. Canadian Code for Farm Buildings. (Farm Building Standards). NRC, Ottawa, Ontario.

9. Baxter, S.H. 1969. The environmental complex in livestock housing. Farm Building Report No. 4. The Scottish Farm Buildings Investigation Unit, Aberdeen, Scotland.

10. Baxter, S.H. 1973. Personal Communication. The Scottish Farm Buildings Investigation Unit, Aberdeen, Scotland.

11. Beckett, F.E. and C.G. Vidrine. 1970. A mathematical model of heat transfer in a pig. Trans. Amer. Soc. Agr. Eng., 13: 450-454.

12. Beckwith, T.G. and N.L. Buck. 1969. Mechanical Measurements. Addison-Wesley Publishing Co. Inc., Reading, Massachusetts.

13. Bluffington, D.E., K.A. Jordon and L.L. Boyd. 1972. Heat production of active, growing turkeys. Paper No. 72-905. Amer. Soc. Agr. Eng., St. Joseph, Michigan 49085.

14. Bond, T.E., H. Heitman, Jr., and C.F. Kelly. 1965. Effects of increased air velocities on heat and moisture loss and growth of swine. Trans. Amer. Soc. Agr. Eng., 8: 167-169, 174.

15. Bond, T.E., C.F. Kelly and H. Heitman, Jr. 1952. Heat and moisture loss from swine. Agric. Eng., 33: 148-152.

16. Bond, T.E., C.F. Kelly and H. Heitman, Jr. 1959. Hog house air-conditioning and ventilation data. Trans. Amer. Soc. Agr. Eng., 2: 1-4.

17. Bond, T.E., C.F. Kelly and H. Heitman, Jr. 1963. Effect of diurnal temperature upon swine heat loss and well-being. Trans. Amer. Soc. Agr. Eng., 6: 132-135.

18. Buchanan, L.C. 1969. Effect of evaporative cooling and intermittent spraying on swine performance. Unnumbered Paper, Can. Soc. Agr. Eng., Suite 907, 151 Slater St., Ottawa, Ontario.

19. Brown, H.P., A.J. Panshin and C.C. Forsaith. 1952. Textbook of Wood Technology. Volume II, McGraw-Hill Book Company, New York.

20. Butchbaker, A.F. and M.D. Shanklin. 1964. Partitional heat losses of new-born pigs as affected by air temperature, absolute humidity, age and body weight. Trans. Amer. Soc. Agr. Eng., 7: 380-383.

21. Butchbaker, A.F., M.D. Paine and R. Shirley. 1973. Uses of a beef animal mathematical model to determine environmental requirement. Paper No. 73-424. Amer. Soc. Agr. Eng., St. Joseph, Michigan 49085.

22. Campbell, W.D. and J.B. McQuitty. 1972. An evaluation of harvest simulation as an aid to decision making. Can. Agr. Eng., 14: 11-14.

23. Carson, W.M. 1971. Digital modelling for maximum swine profit. Can. Agr. Eng., 14: 47-51.

24. Chestnut, H. 1965. Systems Engineering Tools. John Wiley and Sons, Inc., New York.

25. Churchman, C.W. 1968. The Systems Approach. Dell Publishing Co., Inc., New York, N.Y.

26. Computer Sciences Canada. 1973. Data. Volume 2. Suite 367, Place du Canada, Montreal 101, Quebec.

27. Constable, R. 1973. Personal Communication. Regional Agricultural Engineer, Engineering and Home Design Branch, Family Farm Division, Alberta Agriculture, Edmonton.

28. Cress, P., P. Dirksen, and J.W. Graham. 1970. Fortran IV With Watfor and Watfiv. Prentice-Hall, Inc., Englewood Cliffs, N.J.

29. Culver, A.A., F.N. Andrews, J.H. Conrad and T.L. Noffsinger. 1960. Effectiveness of water sprays and a wallow on cooling and growth of swine in normal environment. J. An. Sci., 19: 421-422.

30. Department of Chemical and Petroleum Engineering. 1970. DACS CSMP User Manual. Chem. Pet. Eng. Dept., University of Alberta, Edmonton.

31. DIN 18910. 1963. German Industrial Norm (English Translation). Germany.

32. Dick, J.B. and P.T. Loader. 1960. Temperatures and humidities in pig houses. National Buildings Studies, Research Paper No. 29, Department of Scientific and Industrial Research, Her Majesty's Stationery Office, London.

33. Dukes, H.H. 1955. The Physiology of Domestic Animals. Comstock Publishing Associates, Ithaca, New York.

34. Ellis, D.O. and F.J. Ludwig. 1962. Systems Philosophy. Prentice Hall, Englewood Cliffs, N.J.

35. Esmay, M.L. 1960. Design analysis for poultry house ventilation. Agric.Eng., 41: 576-578.

36. Esmay, M.L. 1969. Principles of Animal Environment. The AVI Publishing Company, Inc., Westport, Connecticut.

37. Esmay, M.L., M. Saeed and G.D. Wells. 1968. Psychrometrics of summer-ventilation air exchange in windowless poultry houses. Trans. Amer. Soc. Agric. Eng., 11: 78-80, 85.

38. Feddes, J.J.R. and J.B. McQuitty. Effects of beef housing systems on moisture removed by ventilation. Can. Agr. Eng., 15 (2): 113-118.

39. Feddes, J.J.R., J.B. McQuitty and G.W. Sadler. 1973. Modelling the dynamic thermal characteristics of confinement livestock housing. Can. Agr. Eng., 15: 54-58.

40. Forest Products Laboratory. 1955. Wood Handbook. Agricultural Handbook No. 72, U.S. Dept. of Agric., Washington, D.C.

41. Gaboury, J.A.M. 1968. Conversion factors and weights and measures. Dominion Steel and Coal Corporation, Ltd., Montreal, Quebec.

42. Good, L.D. 1971. A mathematical simulation of environmental control in swine buildings. Unpublished M.Sc. Thesis, Department of Agricultural Engineering, Purdue University.

43. Gregory, R.L. 1970. On how little information controls so much behaviour. Ergonomics 13: 25-35.

44. Gunnarson, H.J., A.F. Butchbaker, R.L. Witz and W.E. Dinusson. 1967. Effect of air velocity, air temperature and mean radiant temperature on performance of growing-finishing swine. Trans. Amer. Soc. Agr. Eng., 10: 329-331.

45. Guralnik, D.B. 1959. Webster's New World Dictionary. Concise Edition. Nelson, Foster and Scott Limited, Toronto, Ont.

46. Haartsen, P.I. 1973. Personal Communication. Farm Buildings Institute, Wageningen, Holland.

47. Hahn, L. 1973. Personal Communication. USDA, ARS, Missouri.

48. Hale, O.M., R.L. Givens, J.C. Johnson, Jr. and B.L. Southwell. 1966. Effectiveness of moveable shades and water sprinklers for growing-finishing swine. J. An. Sci., 25: 756-759.

49. Hardin, R.T. 1973. Personal Communication. Department of Animal Science, University of Alberta, Edmonton.

50. Harman, D.J., A.C. Dale and H.W. Jones. 1966. Effect of floor type on required moisture vapor removal rate from swine finishing houses. Trans. Amer. Soc. Agr. Eng., 11: 149-152.

51. Hazen, T.E. and D.W. Mangold. 1960. Functional and basic requirements of swine housing. J. Agr. Eng., 41: 585-590.

52. Heitman, H., Jr. and E.H. Hughes. 1949. The effects of air temperature and relative humidity on the physiological well-being of swine. J. An. Sci., 8: 384-387.

53. Heitman, H., Jr., C.F. Kelly and T.E. Bond. 1958. Ambient air temperature and weight gain in swine. J. An. Sci., 17: 62-67.

54. Heitman, H., Jr., T.E. Bond, C.F. Kelly and L. Hahn. 1959. Effects of modified summer environment on swine performance. J. An. Sci., 18: 1367-1372.

55. Hinkle, C.N. 1968. Missing data for swine housing ventilation systems. Paper No. 68-947. Amer. Soc. Agr. Eng., St. Joseph, Michigan 49085.

56. Höglund, C.R. and J.L. Albright. 1970. Economics of housing diary cattle. A review. J. Dairy Science, 53 (11): 1549-1559.

57. Höglund, B.I., G.P. Mitalas and D.G. Stephenson. 1967. Surface temperatures and heat fluxes for flat roofs. Building Science, 2: 29-36. Pargamon Press, London, England.

58. Jordon, K.A. and A.J. Barwick. 1965. Periodic analog for ventilation design. Trans. Amer. Soc. Agr. Eng., 8 (2): 223-226, 229.

59. Jordon, K.A., A.J. Barwick and J.A. Deshazer. 1968. Frequency analyses of weather for estimation of temperature fluctuations in animal shelters. Trans. Amer. Soc. Agr. Eng., 11 (1): 98-103.

60. Jorgenson, R. 1961. Fan Engineering. Buffalo Forge Co., Buffalo, N.Y.

61. Kelly, C.F. 1960. Effects of thermal environment on beef cattle. Agric. Eng., 41: 613-614.

62. Kimura, K. and D.G. Stephenson. 1969. Solar radiation on cloudy days. Research Paper No. 418, Division of Building Research, NRC, Ottawa.

63. Lievers, K.W. 1971. A GPSS cost-benefit simulation of forage handling. Unpublished M.Sc. Thesis, Department of Agricultural Engineering, University of Alberta, Edmonton.

64. Longhouse, A.D. 1967. Designing poultry house ventilation and insulation requirements based upon calorimetric data and psychrometric relationships. Trans. Amer. Soc. Agric. Eng., 10: 512-514, 516.

65. Longhouse, A.D., H. Ota and W. Ashby. 1960. Heat and moisture design data for poultry housing. Agric. Eng., 41: 567-574.

66. MacAuley, F.G. 1972. Simulation as an aid to decision making. Working Paper AE/72/17, University of Guelph, Guelph, Ontario.

67. MacHardy, F.V. 1962. The mechanization and control of farmstead operations. Can. Agr. Eng., 4: 18-19, 29.

68. MacHardy, F.V. 1966. A method for sizing farm machinery for weather dependent operations. Can. Agr. Eng., 8: 26-28.

69. Mackay, C.O. and L.T. Wright, Jr. 1944. Periodic heat flow-homogeneous walls or roofs. Trans. Amer. Soc. of Heating and Ventilating Engineers, 50: 293-315.

70. Mackay, C.O. and L.T. Wright, Jr. 1946. Periodic heat flow-composite walls or roofs. Trans. of Amer. Soc. of Heating and Ventilating Engineers, 52: 283-296.

71. Mangold, D.W., T.E. Hazen and V.W. Hays. 1967. Effect of air temperature on performance of growing-finishing swine. Trans. Amer. Soc. Agr. Eng., 10: 320-321.

72. McQuitty, J.B. and E.M. Barber. 1972. Annotated Bibliography of Farm Animal Wastes. Report EPS 3-WP-72-1, Water Pollution Control Directorate, Environment Canada, Ottawa, Ontario. 2352 ref. 882 pp.

73. Mitalas, G.P. 1968. Calculation of transient heat flow through walls and roofs. Paper No. 2086, Trans. A.S.H.R.A.E., 74 (2): 182-186.

74. Mitalas, G.P. and J.G. Arseneault. 1967. Fortran IV program to calculate heat flux response factors for multi-layer slab. DBR Computer Program No. 26, Division of Building Research, N.R.C., Ottawa.

75. Mitalas, G.P. and J.G. Arseneault. 1972. Fortran IV program to calculate z-transfer functions for the calculation of transient heat transfer through walls and roofs. DBR Computer Program No. 33, Division of Building Research, N.R.C., Ottawa.

76. Mitalas, G.P., D.G. Stephenson and D.C. Baxter. 1960. Use of an analog computer for room air-conditioning calculations. Research Paper No. 114, Division of Building Research, N.R.C., Ottawa.

77. Morrison, S.R., T.E. Bond and H. Hertman, Jr. 1966. Effect of moisture loss from swine. Paper No. 66-441, Amer. Soc. Agr. Eng., St. Joseph, Michigan 49085.

78. Morrison, S.R., T.E. Bond and H. Hertman, Jr. 1968. Physiological response of swine to wetting. Paper No. 68-434, Amer. Soc. Agr. Eng., St. Joseph, Michigan 49085.

79. Morrison, S.R., T.E. Bond and H. Heitman, Jr. 1968. Effect of humidity on swine at high temperature. Trans. Amer. Soc. Agr. Eng., 11: 526-528.

80. Mount, L.E. 1968. The Climatic Physiology of the Pig. Edward Arnold Publishers Ltd., London, England.

81. Neubauer, L.W. 1968. Effect of size, shape, color and orientation on temperature characteristics of model buildings. Paper No. 68-413, Amer. Soc. Agr. Eng., St. Joseph, Michigan 49085.

82. Neubauer, L.W. and R.D. Cramer. 1968. Effect of shape of building on interior air temperatures. Trans. of ASAE, 11 (2): 537-539.

83. Paine, M.D. and A.F. Butchbaker. 1971. Dynamic modelling of the thermal state in beef animals. Paper No. 71-596, Amer. Soc. Agr. Eng., St. Joseph, Michigan 49085.

84. Paine, M.D. and G.L. Nelson. 1971. A system control engineering approach to prediction of animal growth/environment interaction. Trans. Amer. Soc. Agr. Eng., 14 (3): 500-504.

85. Phillips, R.E. and M.L. Esmay. 1973. Systems model of summer environment in an egg production facility. Trans. Amer. Soc. Agr. Eng., 16: 152-156.

86. Preston, T.A. 1971. Ideal farm systems design. Work Study Bulletin No. 2, Department of Agricultural Engineering, University of Alberta, Edmonton.

87. Reece, F.N. and J.W. Deaton. 1970. Factors affecting design criteria for ventilation of windowless broiler houses. Trans. Amer. Soc. Agric. Eng., 13: 636-638.

88. Remmele, P.G., M.A. Hellickson and H.G. Young. 1973. Heat and moisture production from a beef building including manure tanks. Paper No. 73-422, Amer. Soc. Agr. Eng., St. Joseph, Michigan 49085.

89. Rodda, E.D. 1972. A systems design study for food production by non-agricultural methods. Paper No. 72-897. Amer. Soc. Agr. Eng., St. Joseph, Michigan 49085.

90. Russell, D.G. and F.V. MacHardy. 1970. Optimum combining time for minimum cost. Can. Agr. Eng., 12: 3-7, 51.

91. Sadler, G.W. 1973. Personal Communication. Department of Mechanical Engineering, University of Alberta, Edmonton.

92. Schoch, R. 1973. Personal Communication. Lehrstuhl Landliche Siedlungsplangung und Entwerten, 7 Stuttgart 1, Germany.

93. Stephenson, D.G. 1967. Tables of solar altitude, azimuth intensity and heat gain factors for latitudes from 43 to 55 degrees north. Technical Paper No. 243, Division of Building Research, N.R.C., Ottawa.

94. Stephenson, D.G. and G.P. Mitalas. 1967. Cooling load calculations by thermal response factor method. Paper No. 2018, Trans. A.S.H.R.A.E., 73 (Part 1): III.2.1-III.2.10.

95. Stephenson, D.G. and G.P. Mitalas. 1971. Calculation of heat conduction transfer functions for multi-layer slabs. Presented at A.S.H.R.A.E. Semi-annual Meeting, Ottawa, Ontario.

96. Strock, C. and R.L. Koral. 1965. Handbook of Air Conditioning, Heating and Ventilating. Second Edition, The Industrial Press, New York.

97. Strombaugh, D.P. and W.L. Roller. 1973. Dynamic model of thermoregulatory control in piglets. Paper No. 73-420, Amer. Soc. Agr. Eng., St. Joseph, Michigan 49085.

98. Teter, N.C., J.A. DeShazer and T.L. Thompson. 1973. Operational characteristics of meat animals. Part III - Broilers. Trans. Amer. Soc. Agr. Eng., 16 (6): 1165-1167.

99. Threlkeld, J.L. 1970. Thermal Environmental Engineering. Second Edition. Prentice-Hall of Canada, Ltd., Toronto.

100. Van Court Hare, Jr. 1967. Systems Analysis: A Dynamic Approach. Harcourt, Brace and World, Inc., New York.

101. Wagner, N.M. 1969. Principles of Operations Research. Prentice-Hall, Inc., Englewood Cliffs, N.J.

102. Weast, R.C. 1968. Handbook of Chemistry and Physics. Forty-ninth Edition. The Chemical Rubber Co., Cleveland, Ohio.

103. Wilson, J.D. 1972. Determining transient heat transfer effects in structures with the use of a digital computer. Trans. Amer. Soc. Agr. Eng., 15: 726-728, 731.

104. Winfield, R.G. 1971. Summer time environmental control in cage layer houses. Can. Agr. Eng., 13: 76-80.

105. Wolfermann, H.F. 1973. Personal Communication. Max-Planck Institute. Fur Landarbeit und Landtechnik, Am Kauzenburg, West Germany.

106. Wolfermann, H.F. and J. Hornig. 1973. Forschungsbericht. (Research report carried out to complete the DIN 18910 - German Industrial Norm) Max-Planck Institut, Bad Kreuznach, Germany.

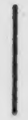
107. Yeck, R.G. 1959. Environmental research with dairy cattle. Agr. Eng., 40: 536-539.

108. Zalik, S. 1971. Outline of Statistical Methods for Biological and Medical Research. Department of Plant Science, University of Alberta, Edmonton.

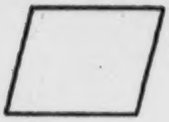
11. APPENDICES

APPENDIX A: PROGRAM FLOW DIAGRAM

The program flow diagram adheres to conventional flow charting procedures. The following is a general description of the notation used.

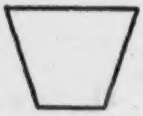


Connector

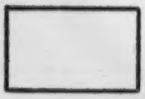


Read data

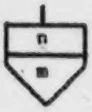
Do-loop* connector



Write data



Control and calculations



Offpage connector
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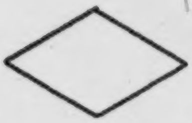
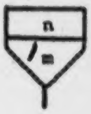
transfer to page = m



Decision



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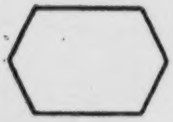


Subroutine

* The Do-loop is a control which facilitates the programming of repetitive computations.

Figure A1. Flow diagram for main program.

MAIN 1

MAIN: An algorithm to determine the dynamic thermal environment within total confinement livestock housing.

START
Note 1.1
1.1
2.1

Note 1.1: The row names for program output parameters are specified

where ROW 1 = clock time,

ROW 2 = solar time,

ROW 3 = solar altitude,

ROW 4 = solar azimuth,

ROW 5 = direct solar intensity,

ROW 6 = intensity of direct solar radiation on surface,

ROW 7 = intensity of total solar radiation on surface,

ROW 8 = solar heat gain factor,

ROW 9 = outside sol-air temperature,

ROW 10 = outside dry-bulb temperature,

ROW 11 = outside wet-bulb temperature,

ROW 12 = longwave radiation at the outside surface,

ROW 13 = shortwave radiation at the outside surface,

ROW 14 = convection at the outside surface,

ROW 15 = heat flux at the outside surface,

ROW 16 = outside surface temperature,

ROW 17 = inside surface temperature,

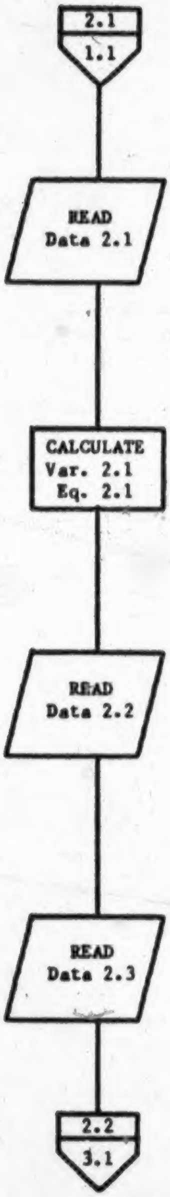
ROW 18 = heat flux at the inside surface,

ROW 19 = convection at the inside surface, and

ROW 20 = inside dry-bulb temperature.

Figure Al. Continued

MAIN 2



Data 2.1:
- simulation period,
- thickness of the attic air cavity,
- emissivity factor for outside wall surface,
- absorptivity factor for outside wall surface,
- absorptivity factor for outside roof surface,
- emissivity factor for outside roof surface,
- heat transfer coefficient for windows installed,
- shading coefficient, and
- relative humidity for the ventilation rate required to remove moisture.

Variable 2.1: total simulation period in hours.

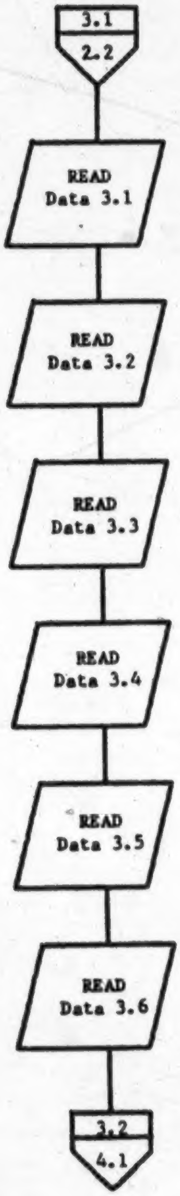
Equation 2.1: $$\left\{\begin{matrix}\text{time} \\ \text{(hrs)}\end{matrix}\right\} = \left\{\begin{matrix}\text{time} & \\ \text{(days -1)} & \end{matrix} \times 24\right\} + 24$$

Data 2.2: hourly heat load for the total simulation period.

Data 2.3: the average hog weight for a maximum of ten groups of hogs.

Figure A1. Continued

MAIN 3


3.1
2.2
READ
Data 3.1
READ
Data 3.2
READ
Data 3.3
READ
Data 3.4
READ
Data 3.5
READ
Data 3.6
3.2
4.1

Data 3.1: the number of hogs in each of the groups of hogs given in Data 2.3.

Data 3.2:
- management factor for moisture production, and
- management factor for sensible heat production.

Data 3.3: hourly barometric pressure for the total simulation period.

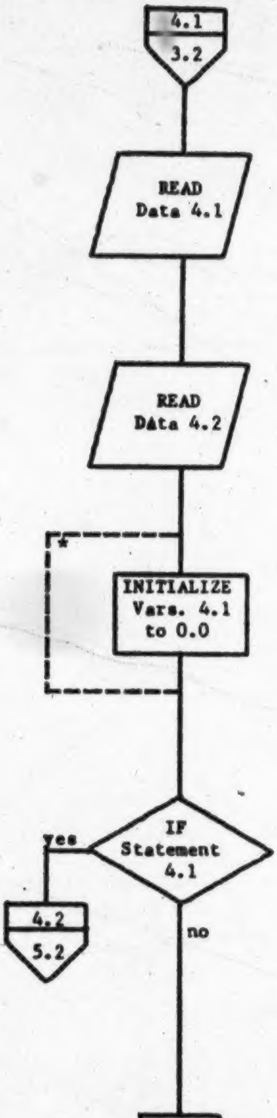
Data 3.4:
- total number of animals confined;
- areas of all walls, doors, roofs and windows; and
- perimeter of the floor.

Data 3.5: hourly ventilation rates for the total simulation period.

Data 3.6: accuracy desired for ventilation rate calculation.

Figure A1. Continued

MAIN 4


4.1
3.2
READ
Data 4.1
READ
Data 4.2
*
INITIALIZE
Vars. 4.1
to 0.0
IF
Statement
4.1
yes
4.2
5.2
no
4.3
5.1

Data 4.1:
- air film conductance for all outside surfaces,
- air film conductance for inside roof surface when a horizontal roof,
- air film conductance for inside wall and door surfaces,
- air film conductance for inside roof surface with a pitched roof,
- emissivity factor for the 'top' attic inside surface, and
- emissivity factor for the 'bottom' attic inside surface.

Data 4.2: ingoing temperature indicator, attic or outside.

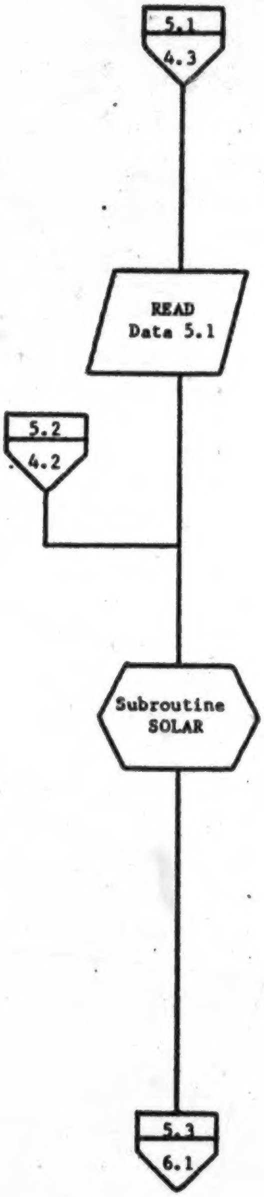
Variables 4.1:
- attic dry-bulb temperatures, and
- attic wet-bulb temperatures.

Statement 4.1: ingoing temperature is equal to outside temperature.

*for all simulation hours.

Figure Al. Continued

MAIN 5



Data 5.1:
- hourly attic dry-bulb temperatures for the total simulation period and
- hourly attic wet-bulb temperatures for the total simulation period.

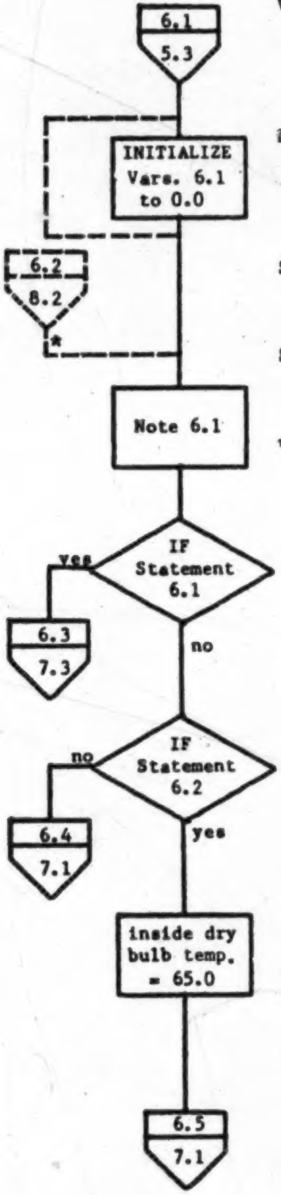
Subroutine SOLAR: An algorithm to find the solar position, the intensity of solar radiation incident on the outer surfaces of the buildings, the sol-air temperature for a surface, and the solar heat gain factors for heat gain through windows.

parameters in: time

parameters out:
- hourly solar output parameters for all surfaces, as specified in ROWS 1 to 11 of Note 1.1,
- equation of time,
- declination,
- latitude of location,
- longitude of location,
- daylight saving time,
- location,
- time zone number, and
- date.

Figure A1. Continued

MAIN 6


6.1
5.3
INITIALIZE
Vars. 6.1
to 0.0
6.2
8.2
*
Note 6.1
IF
Statement
6.1
yes
6.3
7.3
no
IF
Statement
6.2
no
6.4
7.1
yes
inside dry
bulb temp.
= 65.0
6.5
7.1

Variables 6.1: z-transfer function coefficients for walls, roofs, and doors.

Note 6.1: Assign values to the outside dry-bulb temperature and the outside wet-bulb temperature from the solar output matrix.

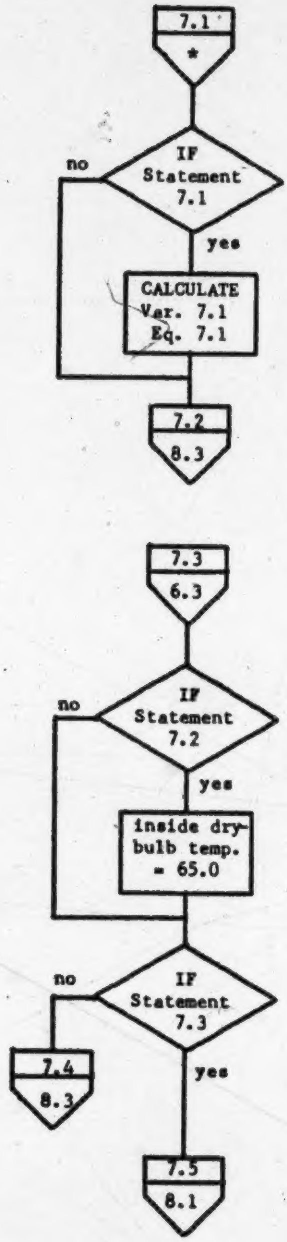
Statement 6.1: ingoing temperature is equal to attic temperature.

Statement 6.2: outside dry-bulb temperature < 60.0°.

*** for all simulation hours.**

Figure Al. Continued

MAIN 7


7.1
*
IF Statement 7.1
no
yes
CALCULATE Var. 7.1 Eq. 7.1
7.2
8.3
7.3
6.3
IF Statement 7.2
no
yes
inside dry-bulb temp. = 65.0
IF Statement 7.3
no
yes
7.4
8.3
7.5
8.1

* 6.4 and 6.5

Statement 7.1: outside dry-bulb temperature $\geq$ 60.0°.

Variable 7.1: inside dry-bulb temperature.

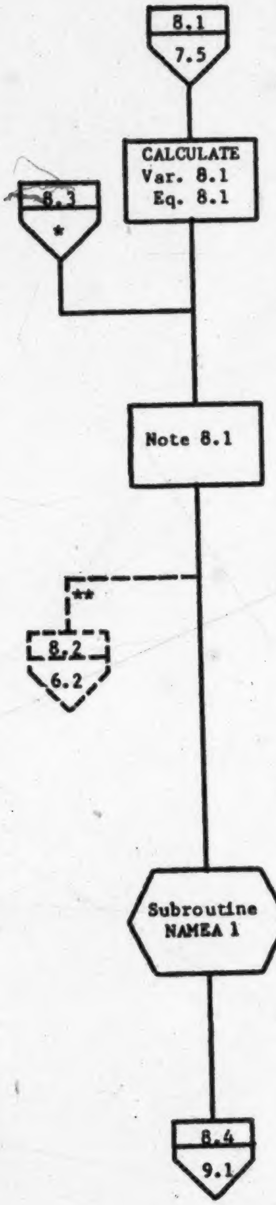
Equation 7.1: $\begin{Bmatrix}\text{inside}\\ \text{dry-bulb}\\ \text{temperature}\end{Bmatrix} = \begin{Bmatrix}\text{outside}\\ \text{dry-bulb}\\ \text{temperature}\end{Bmatrix} + 5.0^\circ$

Statement 7.2: attic dry-bulb temperature< 60°.

Statement 7.3: attic dry-bulb temperature $\geq$ 60°.

Figure A1. Continued

MAIN 8



Variable 8.1: inside dry-bulb temperature.

Equation 8.1: $\left\{\begin{matrix}\text{inside}\\ \text{dry-bulb}\\ \text{temperature}\end{matrix}\right\} = \left\{\begin{matrix}\text{attic}\\ \text{dry-bulb}\\ \text{temperature}\end{matrix}\right\} + 5.0^{\circ}$

* 7.2 and 7.4

Note 8.1: Insert inside dry-bulb temperature into ROW 20 of program output matrix.

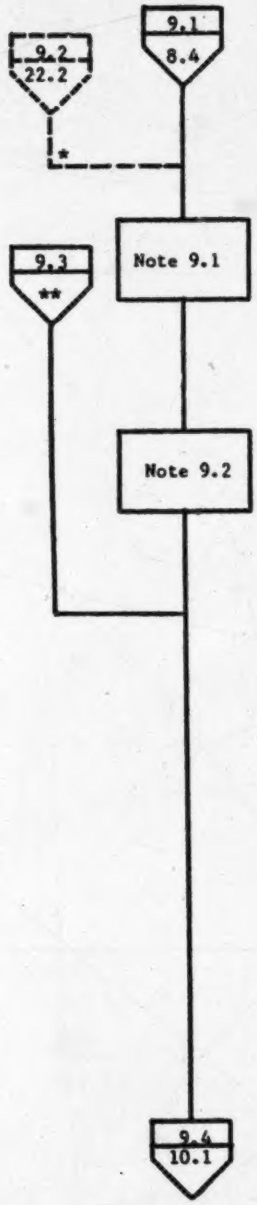
Subroutine NAMEA1: An algorithm to evaluate the z-transfer coefficient for calculation of transient heat flow through walls and roofs.

parameters out: the z-transfer function coefficients for the walls, roofs and doors and the total number of coefficients for each component.

**for all simulation hours

Figure Al. Continued

MAIN 9



* for all simulation hours

Note 9.1: Initialize the trial and error procedure counter to indicate that the procedure has not begun.

** 21.3 and 21.4

Note 9.2: Set the component*** as that for a wall and the component orientation**** to nil.

*** component indication

ICOMP = 1 for wall,

ICOMP = 2 for pitched roof,

ICOMP = 3 for horizontal roof, and

ICOMP = 4 for door.

**** component orientation

ICOMP = 1 for south wall,

ICOMP = 2 for west wall,

ICOMP = 3 for east wall,

ICOMP = 4 for north wall,

ICOMP = 5 for roof slope #1,

ICOMP = 6 for roof slope #2,

ICOMP = 7 for horizontal roof,

ICOMP = 8 for south doors,

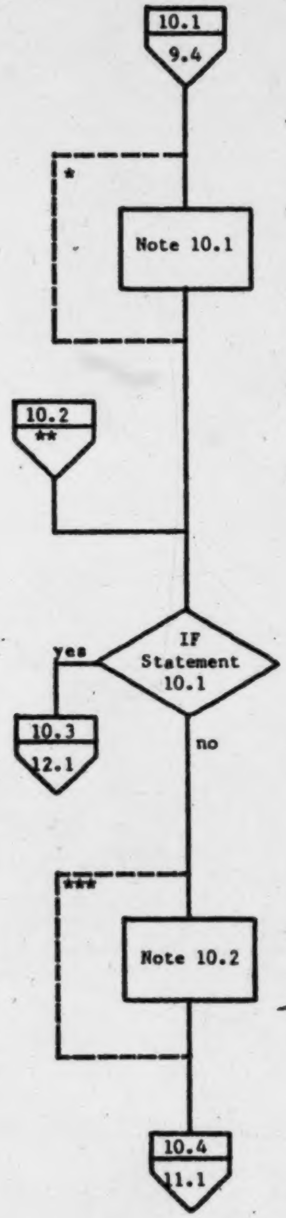
ICOMP = 9 for west doors,

ICOMP =10 for east doors, and

ICOMP =11 for north doors.

Figure A1. Continued

MAIN 10


10.1
9.4
*
Note 10.1
10.2
**
yes
IF Statement 10.1
no
10.3
12.1
***
Note 10.2
10.4
11.1

Note 10.1: Set the z-transfer function coefficients as those for a wall.

* for all z-transfer function coefficients for the wall.

** 13.2, 13.3, 13.6, and 14.2.

Statement 10.1: hour of simulation >7.

*** for all simulation hours.

Note 10.2: Establish the outside and inside surface temperature histories.

$T_{is,-t} = T_{i,t}$

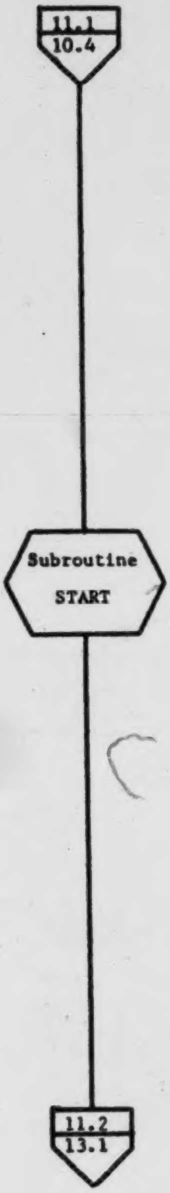
where $T_{is,-t}$ is the inside surface temperature at time, -t, and $T_{i,t}$ is the inside dry-bulb temperature at time, t.

$T_{os,-t} = T_{o,t}$

where $T_{os,-t}$ is the outside surface temperature at time, -t, and $T_{o,t}$ is the outside sol-air temperature at time, t.

Figure A1. Continued

MAIN 11



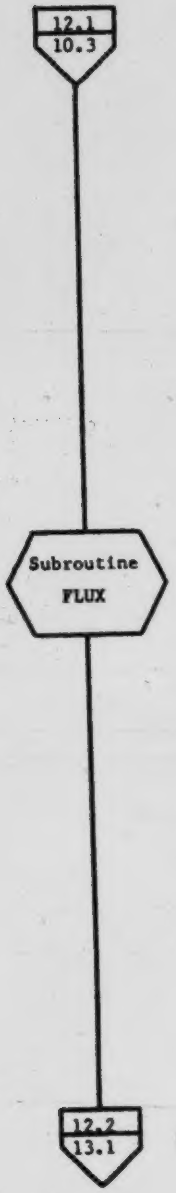
Subroutine START: An algorithm for determining convection, radiation and heat flux for each surface of a building component and then solving for outside and inside surface temperatures for the first seven hours of simulation.

parameters in:
- component indication,
- component orientation,
- z-transfer function coefficients,
- outside surface temperatures,
- inside surface temperatures,
- outside dry-bulb temperature,
- inside dry-bulb temperature,
- emissivity factor for outside wall surface,
- absorptivity factor for outside wall surface,
- absorptivity factor for outside roof surface,
- emissivity factor for outside roof surface,
- outside air film conductance, and
- inside air film conductances.

parameters out:
- output matrix parameters ROW 12 to ROW 20 of Note 1.1.

Figure Al. Continued

MAIN 12



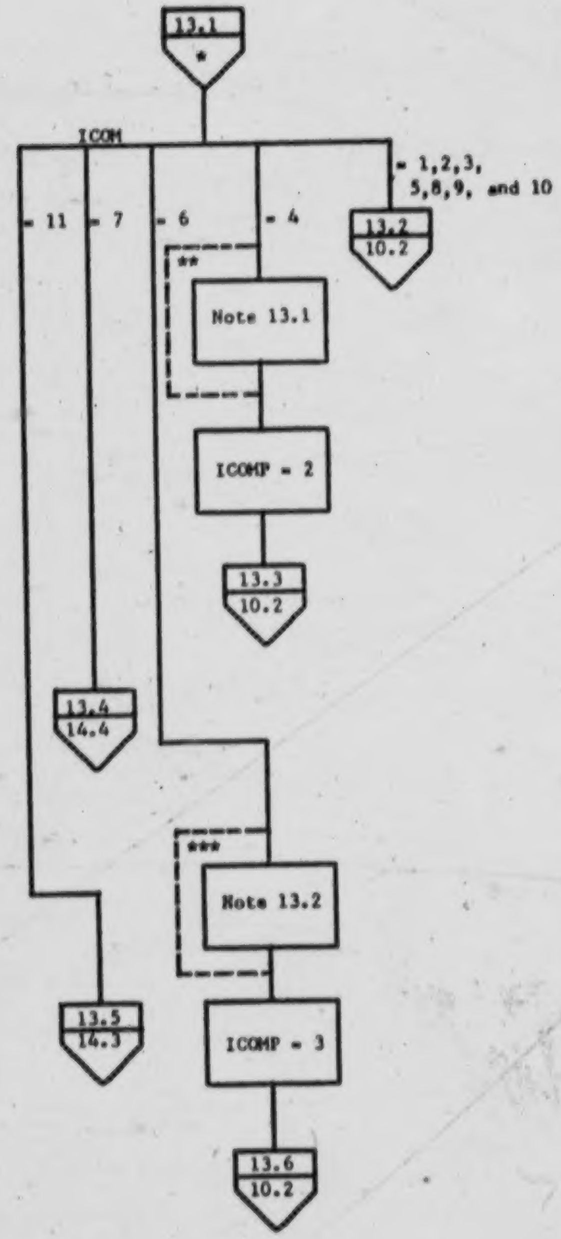
Subroutine FLUX: An algorithm for determining convection, radiation and heat flux for each surface or a building component and then solving for the outside and inside surface temperatures for all simulation hours except the first seven.

parameters in:
- time,
- component indications,
- component orientation,
- z-transfer function coefficients,
- outside dry-bulb temperatures,
- inside dry-bulb temperatures,
- emissivity factor for outside wall surface,
- absorptivity factor for outside wall surface,
- absorptivity factor for outside roof surface,
- absorptivity factor for outside roof surface,
- outside air film conductance, and
- inside air film conductances.

parameters out:
- output matrix parameters of ROW 12 to ROW 20 of Note 1.1.

Figure A1. Continued

MAIN 13


13.1
*
ICOM
= 1,2,3,
5,8,9, and 10
= 11
= 7
= 6
= 4
13.2
10.2
**
Note 13.1
ICOMP = 2
13.3
10.2
13.4
14.4
***
Note 13.2
13.5
14.3
ICOMP = 3
13.6
10.2

* 11.2 and 12.2

Note 13.1: Set the z-transfer function coefficients as those for a pitched roof.

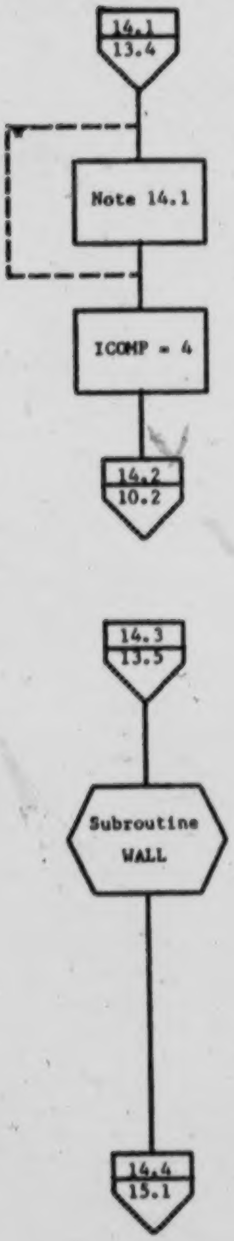
** for all z-transfer function coefficients for the pitched roof.

Note 13.2: Set the z-transfer function coefficients as those for a horizontal roof.

*** for all z-transfer function coefficients for the horizontal roof.

Figure A1: Continued

MAIN 14



Note 14.1: Set the z-transfer function coefficients as those for a door.

* for all z-transfer function coefficients for the door.

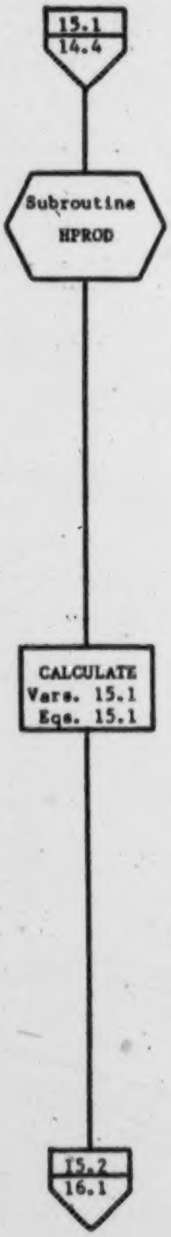
Subroutine WALL: An algorithm for determining the hourly heat flow through the structural components.

parameters in:
- time,
- heat transfer coefficient for the windows,
- outside dry-bulb temperature,
- inside dry-bulb temperature,
- shading coefficient, and
- all areas of structural components.

parameters out:
- heat flow through the walls,
- heat flow through the pitched roofs,
- heat flow through the horizontal roofs,
- heat flow through the windows,
- heat flow through the doors,
- heat flow through the floor, and
- total heat flow through all the components.

Figure A1. Continued

MAIN 15



Subroutine HPROD: An algorithm for determining the sensible heat production and moisture production of the confined animals.

parameters in:
- hog weights for each group of hogs,
- number of animals in each group of hogs,
- management factor for moisture production,
- management factor for sensible heat production,
- time, and
- inside dry-bulb temperature.

parameters out:
- total sensible heat production of the confined animals, and
- total moisture production of the confined animals.

Variables 15.1: sensible heat production and moisture production within the building.

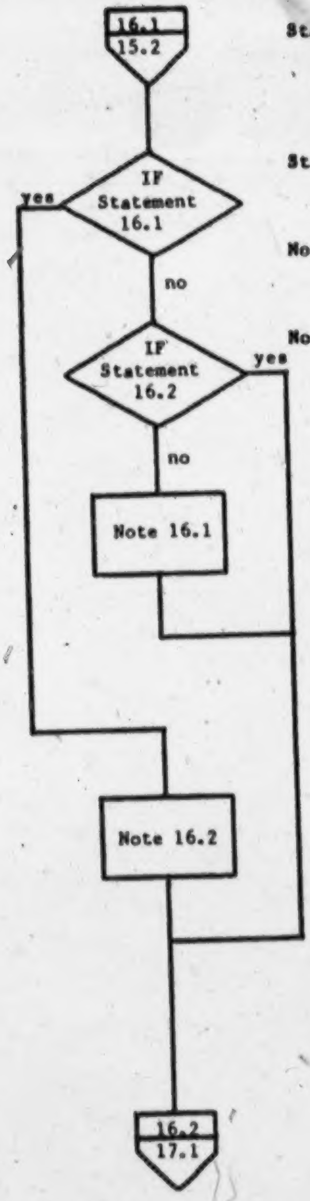
Equations 15.1:

$$\left\{\begin{array}{l}\text{sensible heat}\\ \text{production within}\\ \text{the building}\end{array}\right\} = \left\{\begin{array}{l}\text{sensible heat}\\ \text{production of}\\ \text{the confined}\\ \text{animals}\end{array}\right\} \pm \left\{\begin{array}{l}\text{sensible heat}\\ \text{production of}\\ \text{the furnace or}\\ \text{heater}\end{array}\right\}$$

$$\left\{\begin{array}{l}\text{moisture production}\\ \text{within the building}\end{array}\right\} = \left\{\begin{array}{l}\text{moisture production}\\ \text{of the confined animals}\end{array}\right\}$$

Figure A1. Continued

MAIN 16


16.1
15.2
IF Statement 16.1
yes
no
IF Statement 16.2
yes
no
Note 16.1
Note 16.2
16.2
17.1

Statement 16.1: the ingoing temperature is equal to the outside temperature as per the ingoing temperature indicator.

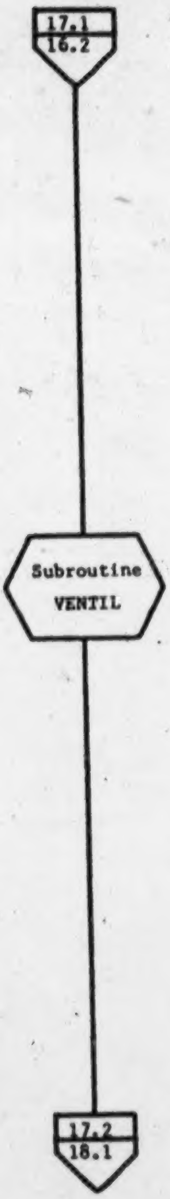
Statement 16.2: the trial and error procedure is in progress.

Note 16.1: The ingoing temperatures are the attic temperatures.

Note 16.2: The ingoing temperatures are the outside temperatures.

Figure A1. Continued

MAIN 17



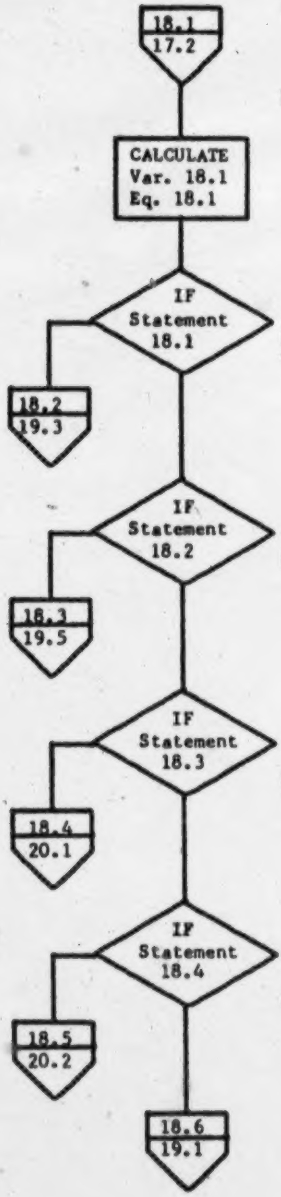
Subroutine VENTIL: An algorithm for determining the psychrometric properties of air and for determining the ventilation rates required to remove heat and moisture.

parameters in:
- time,
- ingoing dry-bulb temperature,
- ingoing wet-bulb temperature,
- barometric pressure,
- total heat flow through the structural components,
- total sensible heat production within the building,
- total moisture production within the building, and
- relative humidity at ventilation rate required to remove moisture.

parameters out:
- ventilation rate required to remove the heat load,
- ventilation rate required to remove the moisture,
- relative humidity for ventilation rate required to remove heat load,
- heat load required to ensure a ventilation rate to remove moisture,
- resultant heat load on building, and
- outside relative humidity.

Figure A1. Continued

MAIN 18



Variable 18.1: **error in ventilation rate calculation.**

Equation 18.1:

$$\left\{\begin{array}{l}\text{error in}\\ \text{ventilation}\\ \text{rate calculation}\end{array}\right\} = \begin{array}{l}\text{absolute}\\ \text{value}\end{array} \left| \frac{\left\{\begin{array}{l}\text{ventilation}\\ \text{rate required}\\ \text{to remove heat}\\ \text{load}\end{array}\right\} - \left\{\begin{array}{l}\text{ventilation}\\ \text{rate in}\\ \text{existing}\\ \text{building}\end{array}\right\}}{\begin{array}{l}\text{Ventilation}\\ \text{rate in}\\ \text{existing}\\ \text{building}\end{array}} \right|$$

Statement 18.1:

$$\left\{\begin{array}{l}\text{error in}\\ \text{ventilation}\\ \text{rate calculation}\end{array}\right\} > 0.75,\ \left\{\begin{array}{l}\text{outside}\\ \text{relative}\\ \text{humidity}\end{array}\right\} > 50.0,$$

$$\text{and} \left\{\begin{array}{l}\text{inside dry-}\\ \text{bulb}\\ \text{temperature}\end{array}\right\} < 75.0$$

Statement 18.2:

$$\left\{\begin{array}{l}\text{error in}\\ \text{ventilation}\\ \text{rate calculation}\end{array}\right\} > 0.50,\ \left\{\begin{array}{l}\text{outside}\\ \text{relative}\\ \text{humidity}\end{array}\right\} > 50.0,$$

$$\text{and} \left\{\begin{array}{l}\text{inside dry-}\\ \text{bulb}\\ \text{temperature}\end{array}\right\} < 75.0$$

Statement 18.3:

$$\left\{\begin{array}{l}\text{error in}\\ \text{ventilation}\\ \text{rate calculation}\end{array}\right\} > 0.25,\ \left\{\begin{array}{l}\text{outside}\\ \text{relative}\\ \text{humidity}\end{array}\right\} > 50.0,$$

$$\text{and} \left\{\begin{array}{l}\text{inside dry-}\\ \text{bulb}\\ \text{temperature}\end{array}\right\} < 75.0$$

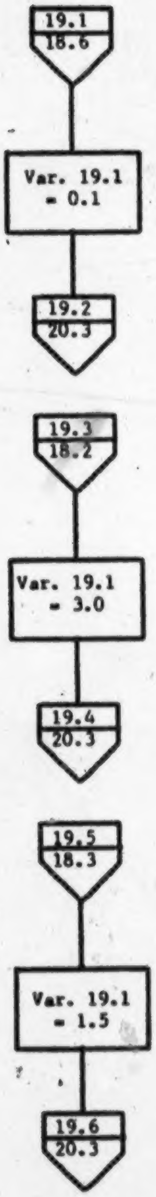
Statement 18.4:

$$\left\{\begin{array}{l}\text{error in}\\ \text{ventilation}\\ \text{rate calculation}\end{array}\right\} > 0.25,\ \left\{\begin{array}{l}\text{outside}\\ \text{relative}\\ \text{humidity}\end{array}\right\} > 50.0$$

$$\text{and} \left\{\begin{array}{l}\text{inside dry-}\\ \text{bulb}\\ \text{temperature}\end{array}\right\} < 75.0$$

Figure Al. Continued

MAIN 19

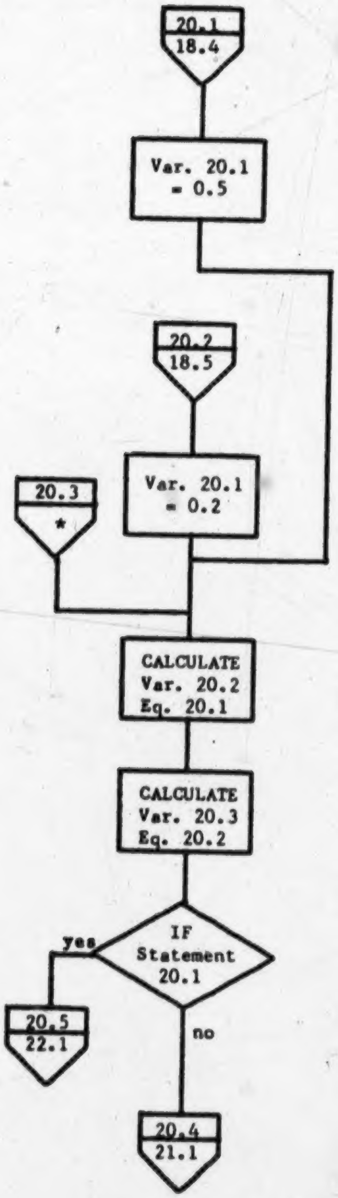


19.1
18.6
Var. 19.1
= 0.1
19.2
20.3
19.3
18.2
Var. 19.1
= 3.0
19.4
20.3
19.5
18.3
Var. 19.1
= 1.5
19.6
20.3

Variable 19.1: increment of change for inside dry-bulb temperature.

Figure A1. Continued

MAIN 20


20.1
18.4
Var. 20.1
= 0.5
20.2
18.5
Var. 20.1
= 0.2
20.3
*
CALCULATE
Var. 20.2
Eq. 20.1
CALCULATE
Var. 20.3
Eq. 20.2
IF
Statement
20.1
yes
no
20.5
22.1
20.4
21.1

Variable 20.1: increment of change for inside dry-bulb temperature.

* 19.2, 19.4, and 19.6

Variable 20.2: permitted error in ventilation rate calculation.

Equation 20.1:

$$\left\{\begin{array}{l}\text{permitted}\\ \text{error in}\\ \text{ventilation}\\ \text{rate}\\ \text{calculation}\end{array}\right\} = \left\{\begin{array}{l}\text{ventilation}\\ \text{rate in}\\ \text{existing}\\ \text{building}\end{array}\right\} \times \left\{\begin{array}{l}\text{accuracy}\\ \text{required in}\\ \text{ventilation}\\ \text{rate}\\ \text{calculation}\end{array}\right\}$$

Variable 20.3: error in ventilation rate calculation.

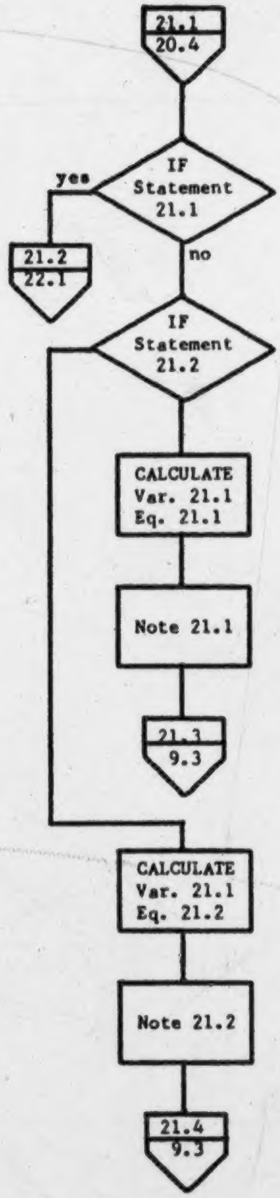
Equation 20.2:

$$\left\{\begin{array}{l}\text{error in}\\ \text{ventilation}\\ \text{rate}\\ \text{calculation}\end{array}\right\} = \left\{\begin{array}{l}\text{ventilation}\\ \text{rate required}\\ \text{to remove}\\ \text{heat load}\end{array}\right\} - \left\{\begin{array}{l}\text{ventilation}\\ \text{rate in}\\ \text{existing}\\ \text{building}\end{array}\right\}$$

Statement 20.1: inside dry-bulb temperature has been increased and decreased; i.e., the desired accuracy cannot be achieved.

Figure A1. Continued

MAIN 21


21.1
20.4
IF
Statement
21.1
yes
21.2
22.1
no
IF
Statement
21.2
CALCULATE
Var. 21.1
Eq. 21.1
Note 21.1
21.3
9.3
CALCULATE
Var. 21.1
Eq. 21.2
Note 21.2
21.4
9.3

Statement 21.1: absolute value

$$\left|\begin{array}{l}\text{error in}\\ \text{ventilation}\\ \text{rate}\\ \text{calculation}\end{array}\right| \leq \left\{\begin{array}{l}\text{permitted error}\\ \text{in ventilation}\\ \text{rate calculation}\end{array}\right\}$$

Statement 21.2:

$$\left\{\begin{array}{l}\text{error in}\\ \text{ventilation}\\ \text{rate}\\ \text{calculation}\end{array}\right\} > 0.0$$

Variable 21.1:

$$\left\{\begin{array}{l}\text{inside dry-}\\ \text{bulb}\\ \text{temperature}\end{array}\right\} = \left\{\begin{array}{l}\text{inside dry-}\\ \text{bulb}\\ \text{temperature}\end{array}\right\} - \left\{\begin{array}{l}\text{increment of}\\ \text{change for}\\ \text{inside dry-}\\ \text{bulb temperature}\end{array}\right\}$$

Note 21.1: Begin trial and error procedure with decreasing inside dry-bulb temperature.

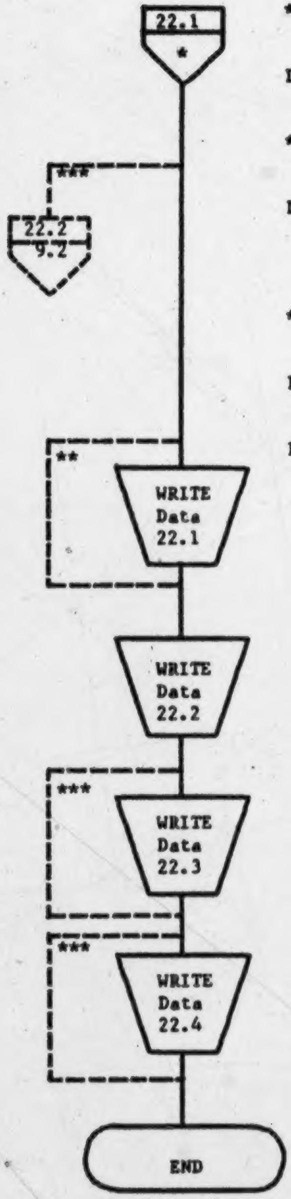
Equation 21.2:

$$\left\{\begin{array}{l}\text{inside}\\ \text{dry-bulb}\\ \text{temperature}\end{array}\right\} = \left\{\begin{array}{l}\text{inside dry-}\\ \text{bulb}\\ \text{temperature}\end{array}\right\} + \left\{\begin{array}{l}\text{increment of}\\ \text{change for}\\ \text{inside dry-}\\ \text{bulb temperature}\end{array}\right\}$$

Note 21.2: Begin trial and error procedure with increasing inside dry-bulb temperature.

Figure A1. Continued

MAIN 22



* 20.5 and 21.2

Data 22.1: program output parameters as listed in Note 1.1.

** for all components and all simulation hours.

Data 22.2:
- number of animals confined, and
- areas of all structural components.

*** for all simulation hours.

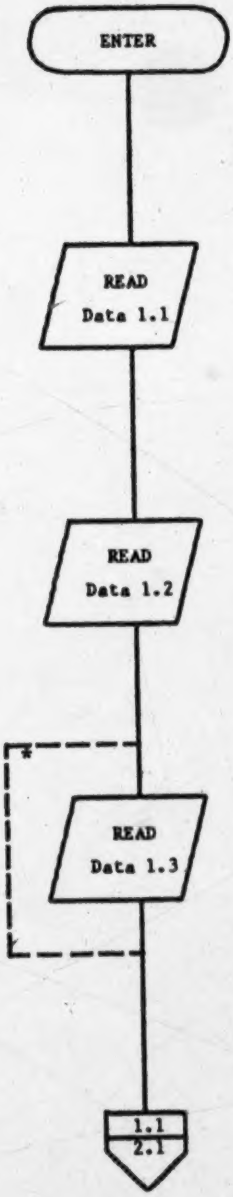
Data 22.3: hourly heat flow through all the structural components.

Data 22.4: hourly ventilation criteria calculated for the model barn:
- input ventilation rate,
- ventilation rate required to remove moisture,
- relative humidity for the ventilation rate required to remove moisture,
- ventilation rate required to remove the heat load,
- relative humidity for the ventilation rate required to remove the heat load,
- heat requirement to ensure a ventilation rate required to remove moisture,
- resultant heat load on the building,
- total sensible heat produced by the animals and furnace,
- outside dry-bulb temperature,
- outside wet-bulb temperature,
- inside dry-bulb temperature,
- moisture production, and
- outside relative humidity.

Figure A2. Flow diagram for SOLAR.

SOLAR 1

SOLAR: An algorthm to find the solar position, the intensity of solar radiation incident on the outer surfaces of buildings, the sol-air temperature for a surface, and the solar heat gain factors for heat gain through windows.



Data 1.1: polynomial coefficients for use in calculation of transmittance and absorptance of glass.

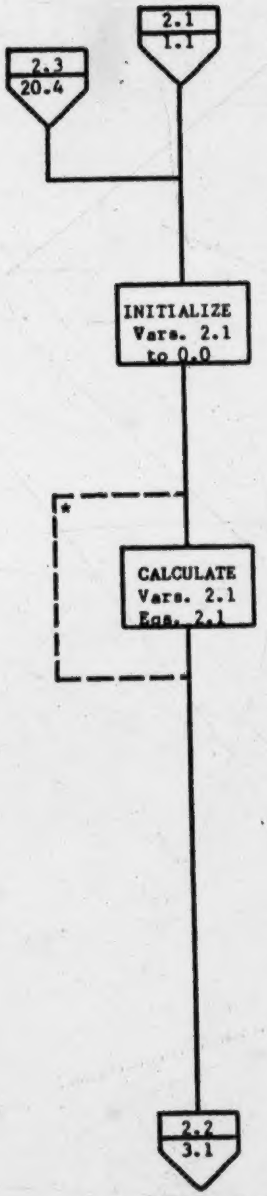
Data 1.2:
- latitude,
- longitude,
- time zone number,
- daylight saving time, and
- location.

Data 1.3:
- surface tilt,
- surface azimuth,
- surface counter, and
- surface indicator.

* for each outside surface of the building.

Figure A2. Continued

SOLAR 2



Variables 2.1: - transmission factor of diffuse radiation for windows, and

- absorption factors of diffuse radiation through outer and inner window pane.

Equations 2.1:

$$\left\{\begin{array}{l}\text{transmission}\\ \text{factor of}\\ \text{diffuse}\\ \text{radiation}\\ \text{for windows}\end{array}\right\} = 2\sum_{j=1}^{6} \frac{\left\{\begin{array}{l}\text{transmission}\\ \text{coefficient}\end{array}\right\}_j}{j+2}$$

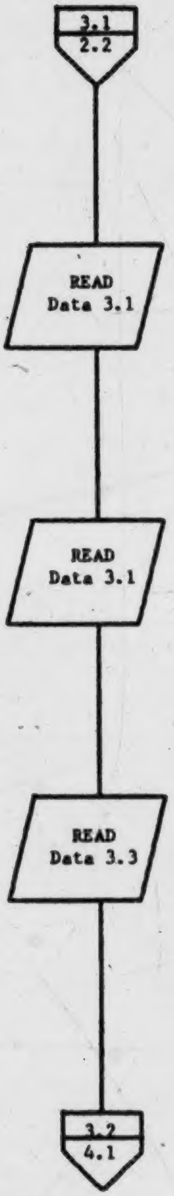
$$\left\{\begin{array}{l}\text{absorption}\\ \text{factor of}\\ \text{diffuse radiation}\\ \text{through outer}\\ \text{window pane}\end{array}\right\} = 2\sum_{j=1}^{6} \frac{\left[\begin{array}{l}\text{absorption}\\ \text{coefficient}\\ \text{for outer}\\ \text{pane}\end{array}\right]_j}{j+2}$$

$$\left\{\begin{array}{l}\text{absorption}\\ \text{factor of}\\ \text{diffuse radiation}\\ \text{through inner}\\ \text{window pane}\end{array}\right\} = 2\sum_{j=1}^{6} \frac{\left\{\begin{array}{l}\text{absorption}\\ \text{coefficient for}\\ \text{inner pane}\end{array}\right\}_j}{j+2}$$

* summation of six coefficients

Figure A2. Continued

SOLAR 3



Data 3.1:
- day of year,
- day of month,
- month, and
- year.

Data 3.2:
- clearness number,
- cloud type,
- ground reflectivity,
- parameter a/h_o *,
- parameter h_o
- inward flowing fraction of the radiation absorbed by the inner pane, and
- inward flowing fraction of the radiation absorbed by the outer pane.

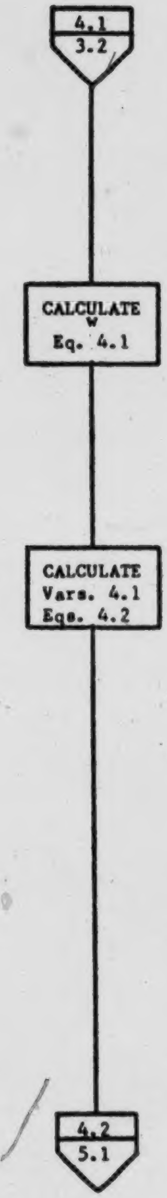
* a = absorptance of the surface for solar radiation, and

h_o = coefficient of heat transfer by radiation and convection at the outer surface.

Data 3.3:
- total cloud cover for each hour,
- outside dry-bulb temperature for each hour, and
- outside wet-bulb temperature for each hour.

Figure A2. Continued

SOLAR 4



Equation 4.1: $w = \frac{2\pi}{366.0}$

Variables 4.1:
- equation of time,
- declination,
- apparent solar constant,
- atmospheric extinction coefficient, and
- sky diffuse factor.

Equation 4.2:

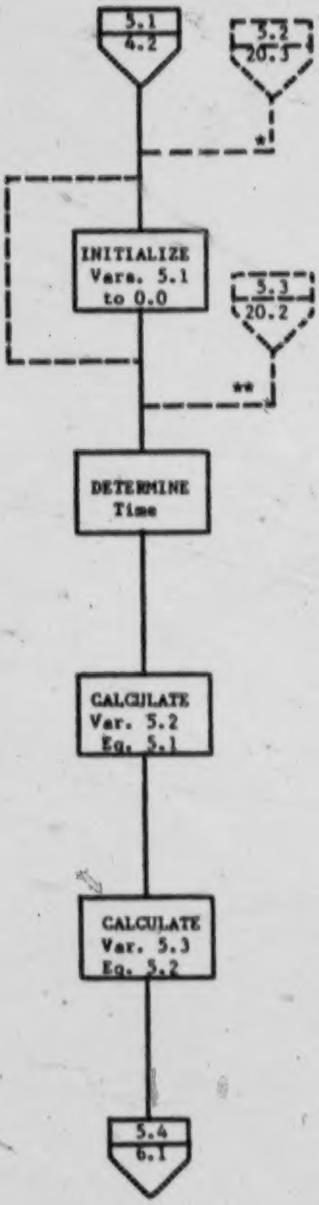
$$\text{Fourier Series} = A_o + A_1 \cos(w \times \text{day of year}) + A_2 \cos(2 \times w \times \text{day of year}) + A_3 \cos(3 \times w \times \text{day of year}) + B_1 \sin(w \times \text{day of year}) + B_2 \sin(2 \times w \times \text{day of year}) + B_3 \sin(3 \times w \times \text{day of year})$$

where:

	A_o	A_1	A_2	A_3	B_1	B_2	B_3
equation of time	0.302	-22.93	-0.229	-0.243	3.851	0.002	-0.055
declination	0.0	0.007	-0.05	-0.0015	-0.122	-0.156	-0.005
apparent solar constant	368.44	24.52	-1.14	-1.09	0.58	-0.18	0.28
atmospheric extinction	0.1717	-0.0344	0.0032	0.0024	-0.0043	0.0	-0.0008
sky diffuse factor	0.0905	-0.0410	0.0073	0.0015	-0.0034	0.0004	-0.0006

Figure A2. Continued

SOLAR 5


5.1
4.2
5.2
20.3
*
INITIALIZE
Vars. 5.1
to 0.0
5.3
20.2
**
DETERMINE
Time
CALCULATE
Var. 5.2
Eq. 5.1
CALCULATE
Var. 5.3
Eq. 5.2
5.4
6.1

Variables 5.1: solar output variables.

Variable 5.2: sunrise and sunset time, radians.

Equation 5.1: $\left\{\begin{matrix}\text{sunrise and}\\ \text{sunset time}\end{matrix}\right\} = \cos^{-1}\left\{\begin{matrix}-\tan\text{ (latitude)}\\ \times\tan\text{ (declination)}\end{matrix}\right\}$

Variable 5.3: hour angle, degrees.

Equation 5.2:

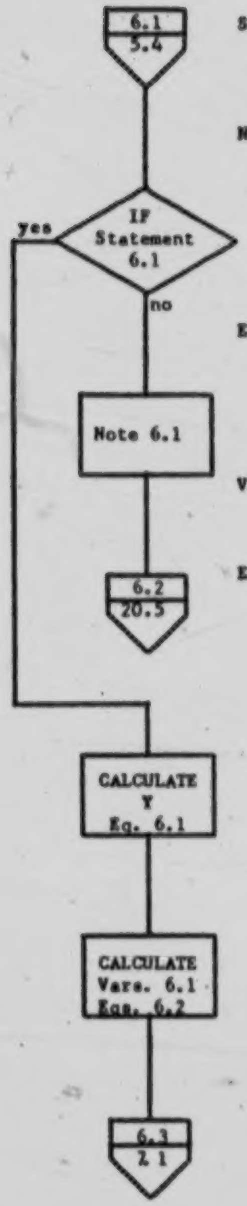
$$\left\{\begin{matrix}\text{hour}\\ \text{angle}\end{matrix}\right\} = 15.0 \times \left[\text{time} - 12.0 + \left\{\begin{matrix}\text{time}\\ \text{zone}\\ \text{number}\end{matrix}\right\} + \left\{\frac{\text{equation of time}}{60.0}\right\} - \left\{\begin{matrix}\text{daylight}\\ \text{saving}\\ \text{time}\end{matrix}\right\}\right] - \text{longitude}$$

* for each outside surface of the building

**for each of the 24 hours of the day.

Figure A2. Continued

SOLAR 6



Statement 6.1: $\text{absolute value} \bigg/ \text{hour angle} \bigg/ \leq \text{absolute value} \bigg/ \text{sunrise and sunset time} \bigg/$

Note 6.1: The intensity of total solar radiation incident on the surface is nil. Therefore,

$$\left\{\begin{matrix}\text{sol-air} \\ \text{temperature}\end{matrix}\right\} = \left\{\begin{matrix}\text{outside dry-bulb} \\ \text{temperature}\end{matrix}\right\}$$

Equation 6.1:

$$Y = \left\{\begin{matrix}\text{sunrise} \\ \text{and} \\ \text{sunset} \\ \text{time}\end{matrix}\right\} \times \left\{\frac{12.0}{\pi}\right\}$$

Variables 6.1: sunrise and sunset time, hour.

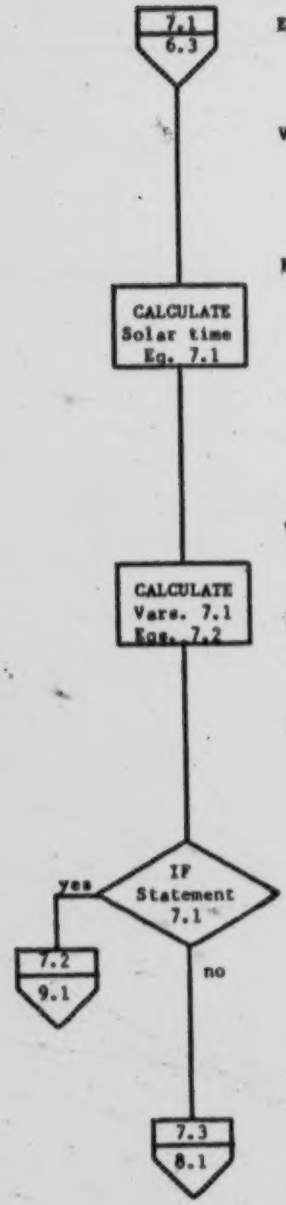
Equations 6.2:

$$\left\{\begin{matrix}\text{sunrise} \\ \text{time}\end{matrix}\right\} = 12.0 - Y - \left\{\frac{\text{equation of time}}{60.0}\right\} - \left\{\begin{matrix}\text{time} \\ \text{zone} \\ \text{number}\end{matrix}\right\} + \left\{\begin{matrix}\text{daylight} \\ \text{saving} \\ \text{time}\end{matrix}\right\} + \left\{\frac{\text{latitude}}{15.0}\right\}$$

$$\left\{\begin{matrix}\text{sunset} \\ \text{time}\end{matrix}\right\} = 24.0 - \left\{\begin{matrix}\text{sunrise} \\ \text{time}\end{matrix}\right\}$$

Figure A2. Continued

SOLAR 7


7.1
6.3
CALCULATE
Solar time
Eq. 7.1
CALCULATE
Vars. 7.1
Eqs. 7.2
IF
Statement
7.1
yes
no
7.2
9.1
7.3
8.1

Equation 7.1: $\left\{\begin{matrix}\text{solar}\\ \text{time}\end{matrix}\right\} = \frac{\text{hour angle (degrees)}}{15.0}$

Variables 7.1: direction cosines of the direct solar beam; Cos (z), Cos (w) and Cos (s).

Equations 7.2: $\cos(z) = \sin(\text{latitude}) \sin(\text{declination}) + \cos(\text{latitude}) \cos(\text{declination}) \cos(\text{hour angle}).$

$\cos(w) = \cos(\text{declination}) \sin(\text{hour angle}).$

$\cos(s) = \left\{1.0 - \cos^2(z) - \cos^2(w)\right\}^{1/2}.$

Variable 7.2: solar altitude.

Equation 7.3: $\left\{\begin{matrix}\text{solar}\\ \text{altitude}\end{matrix}\right\} = \sin^{-1}(\cos(z))$

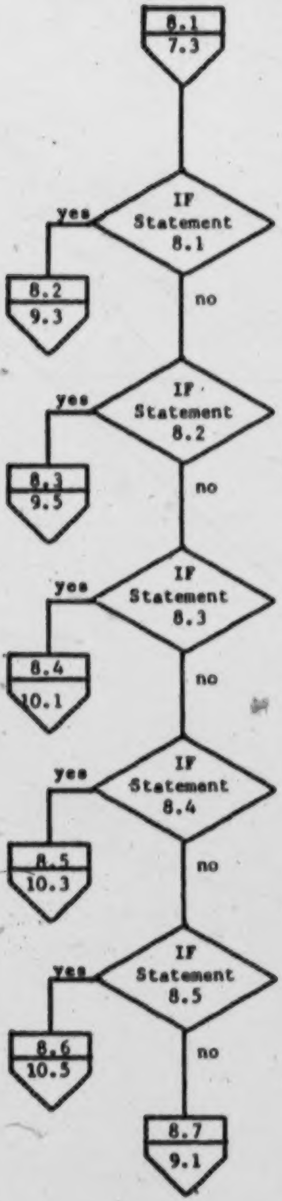
Statement 7.1: $\left\{\begin{matrix}\text{cloud}\\ \text{type}\end{matrix}\right\}$ = cirrus or cirrostratus

and

$\left\{\begin{matrix}\text{solar}\\ \text{altitude}\end{matrix}\right\} \leq 45^\circ$

Figure A2. Continued

SOLAR 8



8.1
7.3
IF Statement 8.1
yes
8.2
9.3
no
IF Statement 8.2
yes
8.3
9.5
no
IF Statement 8.3
yes
8.4
10.1
no
IF Statement 8.4
yes
8.5
10.3
no
IF Statement 8.5
yes
8.6
10.5
no
8.7
9.1

Statement 8.1: $\left\{\begin{array}{l}\text{cloud}\\ \text{type}\end{array}\right\} =$ cirrus or cirrostratus

and

$\left\{\begin{array}{l}\text{solar}\\ \text{altitude}\end{array}\right\} > 45^\circ$

Statement 8.2: $\left\{\begin{array}{l}\text{cloud}\\ \text{type}\end{array}\right\} =$ stratus

and

$\left\{\begin{array}{l}\text{solar}\\ \text{altitude}\end{array}\right\} \leq 45^\circ$

Statement 8.3: $\left\{\begin{array}{l}\text{cloud}\\ \text{type}\end{array}\right\} =$ stratus

and

$\left\{\begin{array}{l}\text{solar}\\ \text{altitude}\end{array}\right\} > 45^\circ$

Statement 8.4: $\left\{\begin{array}{l}\text{cloud}\\ \text{type}\end{array}\right\} \neq$ stratus, cirrus or cirrostratus

and

$\left\{\begin{array}{l}\text{solar}\\ \text{altitude}\end{array}\right\} \leq 45^\circ$

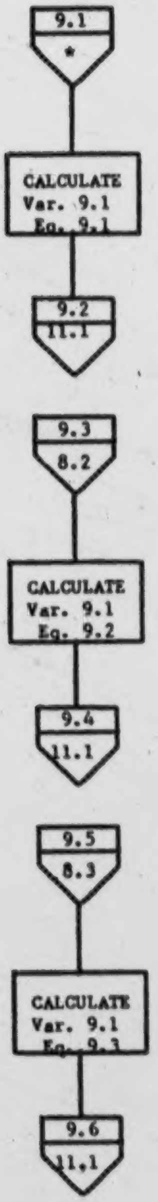
Statement 8.5: $\left\{\begin{array}{l}\text{cloud}\\ \text{type}\end{array}\right\} \neq$ stratus, cirrus or cirrostratus

and

$\left\{\begin{array}{l}\text{solar}\\ \text{altitude}\end{array}\right\} > 45^\circ$

Figure A2. Continued

SOLAR 9



* 7.2 and 8.7

Variable 9.1: cloud cover modifier.

Equation 9.1:

$$\left\{\begin{matrix}\text{cloud}\\\text{cover}\\\text{modifier}\end{matrix}\right\} = 0.598 + 0.00026\left\{\begin{matrix}\text{total}\\\text{cloud}\\\text{cover}\end{matrix}\right\} + 0.0021\left\{\begin{matrix}\text{total}\\\text{cloud}\\\text{cover}\end{matrix}\right\}^2 - 0.00035\left\{\begin{matrix}\text{total}\\\text{cloud}\\\text{cover}\end{matrix}\right\}^3$$

Equation 9.2:

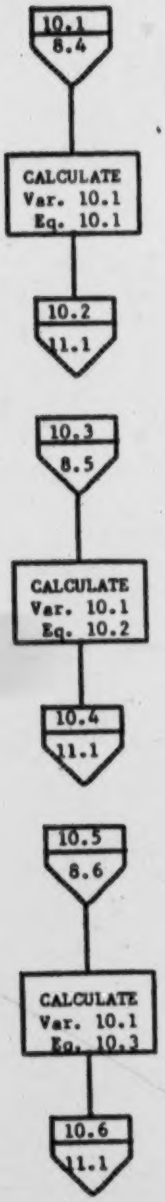
$$\left\{\begin{matrix}\text{cloud}\\\text{cover}\\\text{modifier}\end{matrix}\right\} = 0.908 - 0.03214\left\{\begin{matrix}\text{total}\\\text{cloud}\\\text{cover}\end{matrix}\right\} + 0.0102\left\{\begin{matrix}\text{total}\\\text{cloud}\\\text{cover}\end{matrix}\right\}^2 - 0.00114\left\{\begin{matrix}\text{total}\\\text{cloud}\\\text{cover}\end{matrix}\right\}^3$$

Equation 9.3:

$$\left\{\begin{matrix}\text{cloud}\\\text{cover}\\\text{modifier}\end{matrix}\right\} = 0.849 - 0.01277\left\{\begin{matrix}\text{total}\\\text{cloud}\\\text{cover}\end{matrix}\right\} + 0.0036\left\{\begin{matrix}\text{total}\\\text{cloud}\\\text{cover}\end{matrix}\right\}^2 - 0.00059\left\{\begin{matrix}\text{total}\\\text{cloud}\\\text{cover}\end{matrix}\right\}^3$$

Figure A2. Continued

SOLAR 10



Variable 10.1: cloud cover modifier.

Equation 10.1:

$$\left\{\begin{matrix}\text{cloud}\\\text{cover}\\\text{modifier}\end{matrix}\right\} = 1.010 - 0.01394\left\{\begin{matrix}\text{total}\\\text{cloud}\\\text{cover}\end{matrix}\right\} + 0.00553\left\{\begin{matrix}\text{total}\\\text{cloud}\\\text{cover}\end{matrix}\right\}^2 + 0.00068\left\{\begin{matrix}\text{total}\\\text{cloud}\\\text{cover}\end{matrix}\right\}^3$$

Equation 10.2:

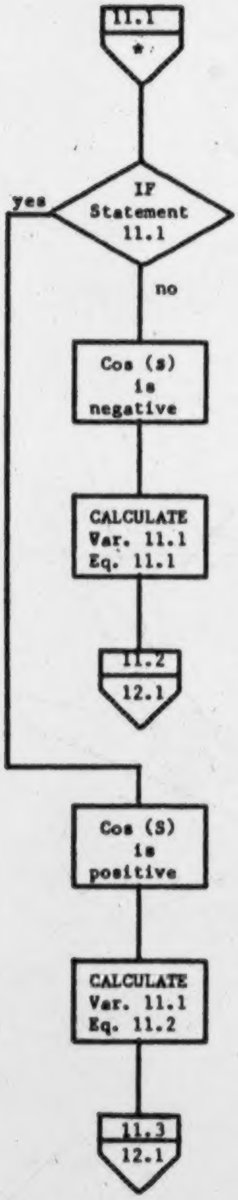
$$\left\{\begin{matrix}\text{cloud}\\\text{cover}\\\text{modifier}\end{matrix}\right\} = 0.724 - 0.00652\left\{\begin{matrix}\text{total}\\\text{cloud}\\\text{cover}\end{matrix}\right\} + 0.00191\left\{\begin{matrix}\text{total}\\\text{cloud}\\\text{cover}\end{matrix}\right\}^2 - 0.00047\left\{\begin{matrix}\text{total}\\\text{cloud}\\\text{cover}\end{matrix}\right\}^3$$

Equation 10.3:

$$\left\{\begin{matrix}\text{cloud}\\\text{cover}\\\text{modifier}\end{matrix}\right\} = 0.959 - 0.02304\left\{\begin{matrix}\text{total}\\\text{cloud}\\\text{cover}\end{matrix}\right\} + 0.00787\left\{\begin{matrix}\text{total}\\\text{cloud}\\\text{cover}\end{matrix}\right\}^2 - 0.00091\left\{\begin{matrix}\text{total}\\\text{cloud}\\\text{cover}\end{matrix}\right\}^3$$

Figure A2. Continued

SOLAR 11


11.1
*
IF Statement 11.1
yes
no
Cos (s) is negative
CALCULATE Var. 11.1 Eq. 11.1
11.2
12.1
Cos (S) is positive
CALCULATE Var. 11.1 Eq. 11.2
11.3
12.1

* 9.2, 9.4, 9.6, 10.2, 10.4 and 10.6

Statement 11.1: $\cos(\text{hour angle}) > \tan\left\{\frac{\text{declination}}{\text{latitude}}\right\}$

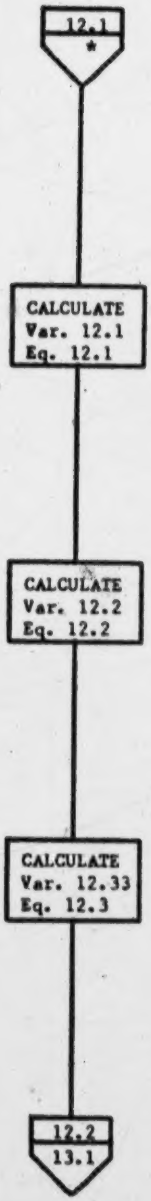
Variable 11.1: solar azimuth.

Equation 11.1: $\left\{\begin{matrix}\text{solar}\\ \text{azimuth}\end{matrix}\right\} = 180.0 - \sin^{-1}\left\{\frac{\cos(w)}{\cos(\text{solar altitude})}\right\}$

Equation 11.2: $\left\{\begin{matrix}\text{solar}\\ \text{azimuth}\end{matrix}\right\} = \sin^{-1}\left\{\frac{\cos(w)}{\cos(\text{solar altitude})}\right\}$

Figure A2. Continued

SOLAR 12



* 11.2 and 11.3

Variable 12.1: intensity of direct normal solar radiation.

Equation 12.1:

$$\left\{\begin{matrix}\text{intensity of}\\ \text{direct normal}\\ \text{solar}\\ \text{radiation}\end{matrix}\right\} = \left\{\begin{matrix}\text{apparent}\\ \text{solar}\\ \text{constant}\end{matrix}\right\} \times \left\{\begin{matrix}\text{clearness}\\ \text{number}\end{matrix}\right\} \times \left\{\begin{matrix}\text{cloud}\\ \text{cover}\\ \text{modifier}\end{matrix}\right\} \times e^{-\left\{\frac{\text{atmospheric extinction coefficient}}{\cos(z)}\right\}}$$

Variable 12.2: sky brightness.

Equation 12.2:

$$\left\{\begin{matrix}\text{sky}\\ \text{brightness}\end{matrix}\right\} = \frac{\left\{\begin{matrix}\text{sky}\\ \text{diffuse}\\ \text{factor}\end{matrix}\right\} \times \left\{\begin{matrix}\text{intensity of}\\ \text{direct normal}\\ \text{solar radiation}\end{matrix}\right\}}{\left\{\text{clearness number}\right\}^2}$$

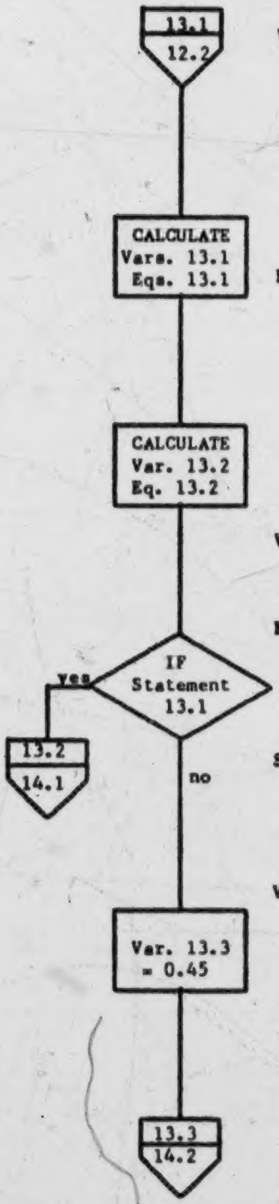
Variable 12.3: ground brightness.

Equation 12.3:

$$\left\{\begin{matrix}\text{ground}\\ \text{brightness}\end{matrix}\right\} = \left[\begin{matrix}\text{ground}\\ \text{reflectivity}\end{matrix}\right] \left[\left\{\begin{matrix}\text{sky}\\ \text{brightness}\end{matrix}\right\} + \left\{\begin{matrix}\text{intensity}\\ \text{of direct}\\ \text{normal solar}\\ \text{radiation}\end{matrix}\right\} \left\{\cos(z)\right\}\right]$$

Figure A2. Continued

SOLAR 13


13.1
12.2
CALCULATE
Vars. 13.1
Eqs. 13.1
CALCULATE
Var. 13.2
Eq. 13.2
IF
Statement
13.1
yes
no
13.2
14.1
Var. 13.3
= 0.45
13.3
14.2

Variables 13.1: direction cosines of normal to surface.

where α - reference axis = vertical

β - reference axis = horizontal to west

γ - reference axis = horizontal to south

Equation 13.1: α = cos (surface tilt angle)

β = sin (surface azimuth angle) x sin (surface tilt angle)

γ = cos (surface azimuth angle) x sin (surface tilt angle)

Variable 13.2: cosine of the angle of incidence.

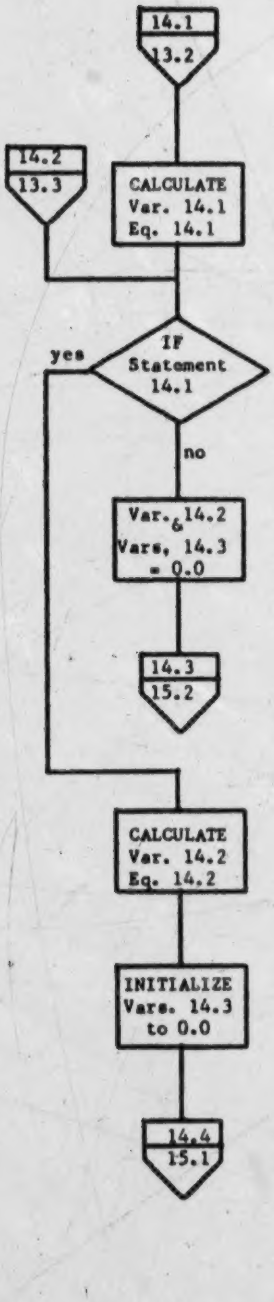
Equation 13.2: $\left\{\begin{array}{l}\text{cosine of the}\\ \text{angle of}\\ \text{incidence}\end{array}\right\} = \alpha \cos(z) + \beta \cos(w) + \gamma \cos(s)$

Statement 13.1: $\left\{\begin{array}{l}\text{cosine of the}\\ \text{angle of}\\ \text{incidence}\end{array}\right\} > -0.20$

Variable 13.3: ratio of sky diffuse radiation on the vertical surface to the sky diffuse radiation on the horizontal surface, Y.

Figure A2. Continued

SOLAR 14


14.1
13.2
14.2
13.3
CALCULATE
Var. 14.1
Eq. 14.1
IF
Statement
14.1
yes
no
Var. & 14.2
Vars, 14.3
= 0.0
14.3
15.2
CALCULATE
Var. 14.2
Eq. 14.2
INITIALIZE
Vars. 14.3
to 0.0
14.4
15.1

Variable 14.1: ratio of sky diffuse radiation on the vertical surface to sky diffuse radiation on the horizontal surface, Y.

Equation 14.1: $Y = 0.55 + 0.437 \left\{\begin{array}{l}\text{cosine of the}\\ \text{angle of}\\ \text{incidence}\end{array}\right\} + 0.313 \left\{\begin{array}{l}\text{cosine of the}\\ \text{angle of}\\ \text{incidence}\end{array}\right\}^2$

Statement 14.1: $\left\{\begin{array}{l}\text{cosine of the}\\ \text{angle of}\\ \text{incidence}\end{array}\right\} > 0.0$

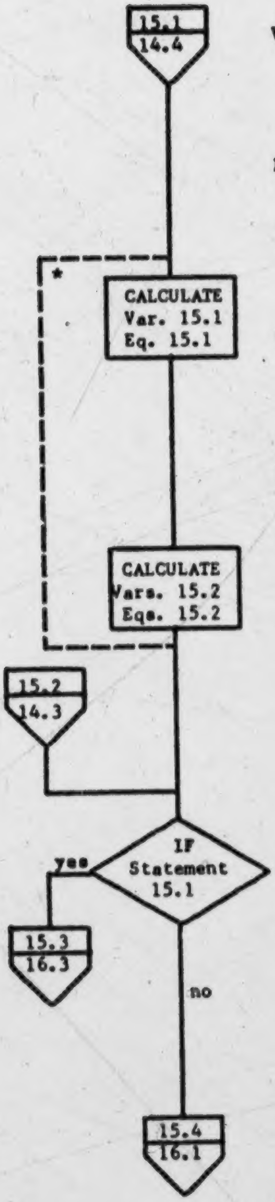
Variable 14.2: intensity of the direct solar radiation incident on surface.

Variables 14.3: transmission factors of direct solar radiation for windows and absorption factors of direct solar radiation through outer and inner window pane.

Equation 14.2: $\left\{\begin{array}{l}\text{intensity of the}\\ \text{direct solar}\\ \text{radiation}\\ \text{incident on}\\ \text{surface}\end{array}\right\} = \left\{\begin{array}{l}\text{intensity of}\\ \text{direct}\\ \text{normal solar}\\ \text{radiation}\end{array}\right\}\left\{\begin{array}{l}\text{cosine}\\ \text{of the}\\ \text{angle of}\\ \text{incidence}\end{array}\right\}$

Figure A2. Continued

SOLAR 15



Variable 15.1: transmission factor of direct solar radiation for windows.

Equation 15.1:

$$\left\{\begin{matrix}\text{transmission}\\ \text{factor of}\\ \text{direct solar}\\ \text{radiation}\\ \text{for windows}\end{matrix}\right\} = \sum_{j=1}^{6} \left\{\begin{matrix}\text{transmission}\\ \text{coefficient}\end{matrix}\right\}_j \times \left\{\begin{matrix}\text{cosine of}\\ \text{angle of}\\ \text{incidence}\end{matrix}\right\}^{j-1}$$

Variables 15.2: absorption factors of direct solar radiation through outer and inner pane.

Equation 15.2:

$$\left\{\begin{matrix}\text{absorption}\\ \text{factor of}\\ \text{direct solar}\\ \text{radiation}\\ \text{through outer}\\ \text{pane}\end{matrix}\right\} = \sum_{j=1}^{6} \left\{\begin{matrix}\text{absorption}\\ \text{coefficient}\\ \text{for outer}\\ \text{pane}\end{matrix}\right\}_j \times \left\{\begin{matrix}\text{cosine}\\ \text{of angle}\\ \text{of}\\ \text{incident}\end{matrix}\right\}^{j-1}$$

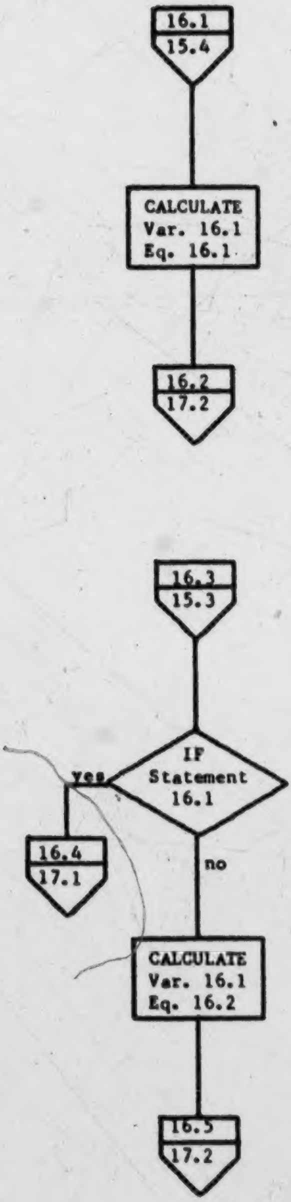
$$\left\{\begin{matrix}\text{absorption}\\ \text{factor of}\\ \text{direct solar}\\ \text{radiation}\\ \text{through inner}\\ \text{pane}\end{matrix}\right\} = \sum_{j=1}^{6} \left\{\begin{matrix}\text{absorption}\\ \text{coefficient}\\ \text{for inner}\\ \text{pane}\end{matrix}\right\}_j \times \left\{\begin{matrix}\text{cosine}\\ \text{of angle}\\ \text{of}\\ \text{incident}\end{matrix}\right\}^{j-1}$$

* summation of six variables.

Statement 15.1: surface tilt angle >0.0; i.e., surface is not horizontal.

Figure A2. Continued

SOLAR 16


16.1
15.4
CALCULATE
Var. 16.1
Eq. 16.1
16.2
17.2
16.3
15.3
IF
Statement
16.1
yes
no
16.4
17.1
CALCULATE
Var. 16.1
Eq. 16.2
16.5
17.2

Variable 16.1: intensity of sky diffuse radiation incident on surface.

Equation 16.1:

$$\begin{Bmatrix}\text{intensity of sky}\\ \text{diffuse radiation}\\ \text{incident on}\\ \text{surface}\end{Bmatrix} = \begin{Bmatrix}\text{intensity of}\\ \text{direct normal}\\ \text{solar}\\ \text{radiation}\end{Bmatrix} \times \begin{Bmatrix}\text{sky}\\ \text{diffuse}\\ \text{factor}\end{Bmatrix}$$

Statement 16.1: surface tilt angle ≠ 90.0, i.e. surface is not vertical.

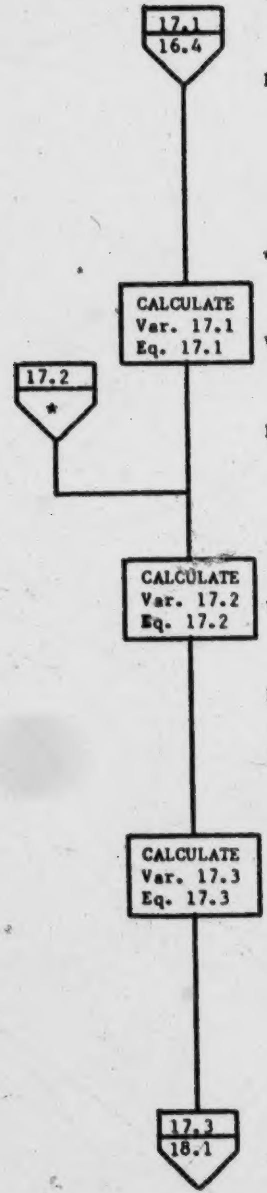
Equation 16.2:

$$\begin{Bmatrix}\text{intensity of}\\ \text{sky diffuse}\\ \text{radiation}\\ \text{incident on}\\ \text{surface}\end{Bmatrix} = \begin{bmatrix}\text{intensity of}\\ \text{direct normal}\\ \text{solar}\\ \text{radiation}\end{bmatrix} \times$$

$$\left[\left\{\begin{pmatrix}\text{sky}\\ \text{diffuse}\\ \text{factor}\end{pmatrix} \times Y\right\} + \left\{\left(\frac{\text{ground reflectivity}}{2.0}\right) \times \left(\begin{matrix}\text{sky}\\ \text{diffuse}\\ \text{factor}\end{matrix} + \sin\begin{pmatrix}\text{solar}\\ \text{altitude}\end{pmatrix}\right)\right\}\right]$$

Figure A2. Continued

SOLAR 17



Variable 17.1: intensity of sky diffuse radiation incident on surface.

Equation 17.1:

$$\left\{\begin{array}{l}\text{intensity of}\\ \text{sky diffuse}\\ \text{radiation}\\ \text{incident on}\\ \text{surface}\end{array}\right\} = \left\{\begin{array}{l}\text{sky}\\ \text{brightness}\end{array}\right\} \times \left\{\frac{1.0 + =}{2.0}\right\}$$

* 16.2 and 16.5

Variable 17.2: intensity of ground diffuse radiation incident on surface.

Equation 17.2:

$$\left\{\begin{array}{l}\text{intensity of}\\ \text{ground diffuse}\\ \text{radiation}\\ \text{incident on}\\ \text{surface}\end{array}\right\} = \left\{\begin{array}{l}\text{ground}\\ \text{brightness}\end{array}\right\} \times \left\{\frac{1.0 - =}{2.0}\right\}$$

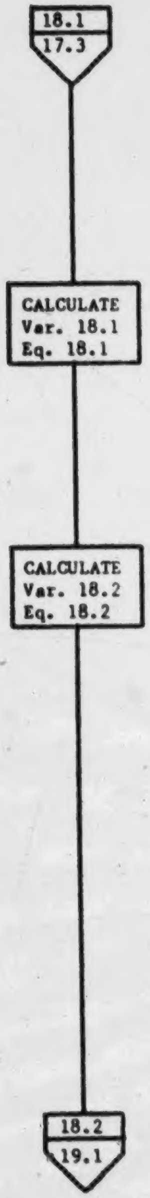
Variable 17.3: intensity of total solar radiation incident on surface.

Equation 17.3:

$$\left\{\begin{array}{l}\text{intensity}\\ \text{of total}\\ \text{solar}\\ \text{radiation}\\ \text{incident on}\\ \text{surface}\end{array}\right\} = \left\{\begin{array}{l}\text{intensity}\\ \text{of direct}\\ \text{solar}\\ \text{radiation}\\ \text{incident on}\\ \text{surface}\end{array}\right\} + \left\{\begin{array}{l}\text{intensity}\\ \text{of ground}\\ \text{diffuse}\\ \text{radiation}\\ \text{incident on}\\ \text{surface}\end{array}\right\} + \left\{\begin{array}{l}\text{intensity}\\ \text{of sky}\\ \text{diffuse}\\ \text{radiation}\\ \text{incident on}\\ \text{surface}\end{array}\right\}$$

Figure A2. Continued

SOLAR 18



Variable 18.1: sol-air temperature.

Equation 18.1:

$$\left\{\begin{matrix}\text{sol-air}\\ \text{temperature}\end{matrix}\right\} = \left\{\begin{matrix}\text{outside}\\ \text{dry-bulb}\\ \text{temperature}\end{matrix}\right\} + \left\{\left[{}^{a}/h_o\right] \times \left[\begin{matrix}\text{intensity of total}\\ \text{solar radiation}\\ \text{incident on surface}\end{matrix}\right]\right\} - \left\{\frac{2 * \left[10.0 - \left(\begin{matrix}\text{total cloud}\\ \text{cover}\end{matrix}\right)\right]}{h_o}\right\}$$

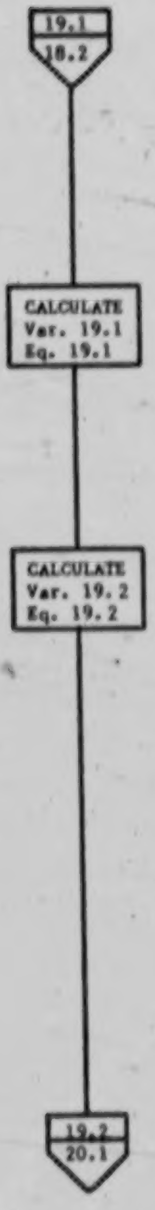
Variable 18.2: solar heat gain factor for direct solar radiation.

Equation 18.2:

$$\left\{\begin{matrix}\text{solar heat}\\ \text{gain factor}\\ \text{for direct}\\ \text{solar}\\ \text{radiation}\end{matrix}\right\} = \left[\begin{matrix}\text{intensity of}\\ \text{direct solar}\\ \text{radiation}\\ \text{incident on}\\ \text{surface}\end{matrix}\right] \times \left[\left\{\begin{matrix}\text{transmission}\\ \text{factor of}\\ \text{direct solar}\\ \text{radiation}\\ \text{for windows}\end{matrix}\right\} + \left\{\begin{matrix}\text{inward-flowing}\\ \text{fraction of}\\ \text{the radiation}\\ \text{absorbed by}\\ \text{the inner pane}\end{matrix}\right\}\left\{\begin{matrix}\text{absorption}\\ \text{factor of}\\ \text{direct solar}\\ \text{radiation}\\ \text{through the}\\ \text{inner pane}\end{matrix}\right\} + \left\{\begin{matrix}\text{inward-flowing}\\ \text{fraction of}\\ \text{the radiation}\\ \text{absorbed by}\\ \text{the outer pane}\end{matrix}\right\}\left\{\begin{matrix}\text{absorption}\\ \text{factor of}\\ \text{direct solar}\\ \text{radiation}\\ \text{through the}\\ \text{outer pane}\end{matrix}\right\}\right]$$

Figure A2. Continued

SOLAR 19



Variable 19.1: solar heat gain factor for diffuse solar radiation.

Equation 19.1:

$$\left\{\begin{array}{l}\text{solar heat}\\\text{gain factor}\\\text{for diffuse}\\\text{solar}\\\text{radiation}\end{array}\right\} = \left[\left[\left\{\begin{array}{l}\text{intensity of}\\\text{ground diffuse}\\\text{radiation}\\\text{incident on}\\\text{surface}\end{array}\right\} + \left\{\begin{array}{l}\text{intensity of}\\\text{sky diffuse}\\\text{radiation}\\\text{incident on}\\\text{surface}\end{array}\right\}\right]\right.$$

$$\times \left[\left[\left\{\begin{array}{l}\text{transmission}\\\text{factor of}\\\text{diffuse}\\\text{radiation for}\\\text{windows}\end{array}\right\} + \right.\right.$$

$$\left\{\begin{array}{l}\text{inward-flowing}\\\text{fraction of}\\\text{the radiation}\\\text{absorbed by}\\\text{the inner pane}\end{array}\right\}\left\{\begin{array}{l}\text{absorption}\\\text{factor of}\\\text{diffuse}\\\text{radiation}\\\text{through inner}\\\text{window pane}\end{array}\right\} +$$

$$\left.\left.\left\{\begin{array}{l}\text{inward-flowing}\\\text{fraction of}\\\text{the radiation}\\\text{absorbed by}\\\text{the outer pane}\end{array}\right\}\left\{\begin{array}{l}\text{absorption}\\\text{factor of}\\\text{diffuse}\\\text{radiation}\\\text{through outer}\\\text{window pane}\end{array}\right\}\right]\right]$$

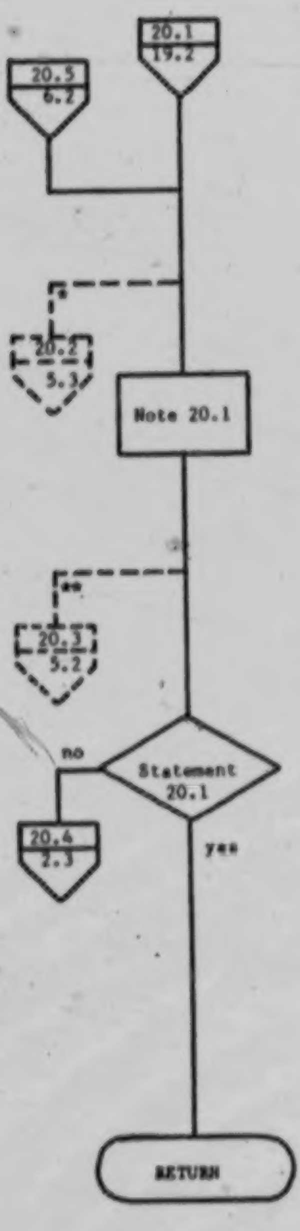
Variable 19.2: solar heat gain factor.

Equation 19.2:

$$\left\{\begin{array}{l}\text{solar heat}\\\text{gain factor}\end{array}\right\} = \left\{\begin{array}{l}\text{solar heat}\\\text{gain factor}\\\text{for direct}\\\text{solar radiation}\end{array}\right\} + \left\{\begin{array}{l}\text{solar heat}\\\text{gain factor}\\\text{for diffuse}\\\text{solar radiation}\end{array}\right\}$$

Figure A2. Continued

SOLAR 20


20.1
19.2
20.5
6.2
*
20.2
5.3
Note 20.1
**
20.3
5.2
no
Statement 20.1
20.4
2.3
yes
RETURN

Note 20.1: Insert the solar output data into the program output matrix after determining what day of simulation the data represents.

Statement 20.1: Are all days of simulation completed?

* for each of the 24 hours of the day.

** for each outside surface of the building.

Figure A3. Flow diagram for subroutines NAMEA1, POLES, MATRIX, ORIGIN, POLYM, SOLVN and FREQRE.

NAMEA1, POLES, MATRIX, ORIGIN, POLYM, SOLVN, FREQRE: Algorithms to derive the z-transfer function coefficients for transient heat transfer through walls and roofs.

These algorithms are not flowcharted here as they have been well documented previously in the publication* for calculation of these functions. These subroutines are presented in Appendix B as presented by the original source and comments are left exactly as presented by the National Research Council. Only minor changes were made in subroutine NAMEA1;

1. The subroutine AIRCAV was called whenever the program read a thickness of 100 feet for a component (as specified for an air cavity). The parameters transferred into AIRCAV were the thickness of the air cavity, the emissivity factors for the surfaces facing the air cavity, and the heat flow direction index for the attic. AIRCAV then calculates the air cavity thermal resistance.
2. The program assigns variable names to the z-transfer function coefficients of all doors walls and roofs for return to the mainline.

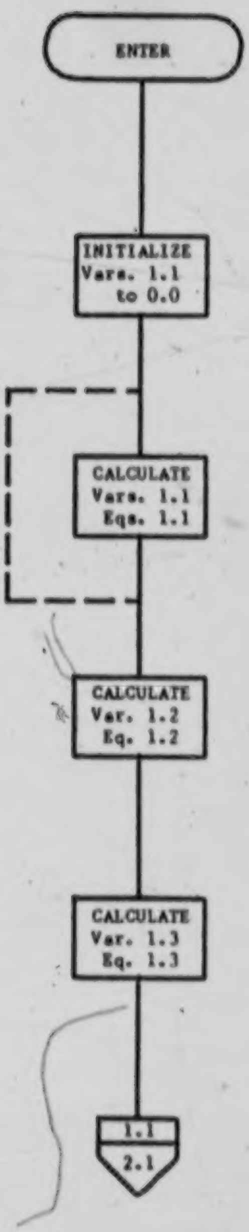
---

* Source: Mitolas, G.P. and J.G. Arseneault. 1972. Fortran IV program to calculate z-transfer through walls and roofs. DBR Computer Program No. 33, Division of Building Research, NRC, Ottawa.

Figure A4. Flow diagram for subroutine AIRCAV.

AIRCAV 1

AIRCAV: An algorithm for determining the thermal resistance across the air cavity in a pitched roof.



Variables.1.1:
- sum of outside sol-air temperatures at sloped roof surfaces, and
- sum of the inside ambient temperature.

Equation 1.1:

$$\left\{\begin{matrix}\text{sum of}\\ \text{sol-air}\\ \text{temperature}\end{matrix}\right\} = \sum_{t=7}^{17} \left[\left\{\begin{matrix}\text{sol-air}\\ \text{temperature}\\ \text{at east}\\ \text{roof slope}\end{matrix}\right\}_t + \left\{\begin{matrix}\text{sol-air}\\ \text{temperature}\\ \text{of west}\\ \text{roof slope}\end{matrix}\right\}\right]$$

$$\left\{\begin{matrix}\text{sum of inside}\\ \text{ambient}\\ \text{temperature}\end{matrix}\right\} = \sum_{t=7}^{17} \left\{\begin{matrix}\text{inside}\\ \text{dry-bulb}\\ \text{temperature}\end{matrix}\right\}_t$$

where t = time

Variable 1.2: average sol-air temperature for roof.

Equation 1.2:

$$\left\{\begin{matrix}\text{average sol-air}\\ \text{temperature}\\ \text{for roof}\end{matrix}\right\} = \frac{\left\{\begin{matrix}\text{sum of sol-air}\\ \text{temperature}\end{matrix}\right\}}{22}$$

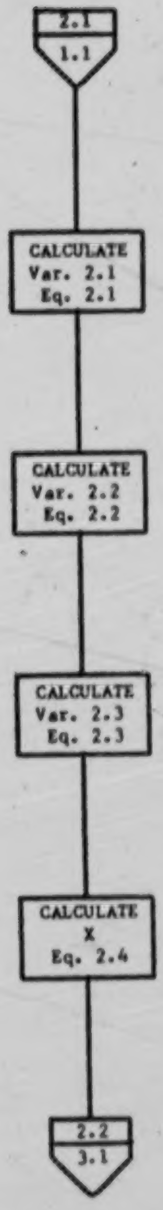
Variable 1.3: average inside ambient temperature.

Equation 1.3:

$$\left\{\begin{matrix}\text{average inside}\\ \text{ambient}\\ \text{temperature}\end{matrix}\right\} = \frac{\left\{\begin{matrix}\text{sum of inside}\\ \text{ambient temperature}\end{matrix}\right\}}{11}$$

Figure A4. Continued

AIRCAV 2



Variable 2.1: temperature difference across the air space.

Equation 2.1:

$$\left\{\begin{array}{l}\text{temperature}\\ \text{difference}\\ \text{across the}\\ \text{air space}\end{array}\right\} = \left\{\begin{array}{l}\text{average}\\ \text{sol-air}\\ \text{temperature}\\ \text{for roof}\end{array}\right\} - \left\{\begin{array}{l}\text{average}\\ \text{inside}\\ \text{ambient}\\ \text{temperature}\end{array}\right\}$$

Variable 2.2: average temperature of the air cavity.

Equation 2.2:

$$\left\{\begin{array}{l}\text{average}\\ \text{temperature}\\ \text{of the air}\\ \text{cavity}\end{array}\right\} = \frac{\left\{\begin{array}{l}\text{average}\\ \text{sol-air}\\ \text{temperature}\\ \text{for roof}\end{array}\right\} + \left\{\begin{array}{l}\text{average}\\ \text{inside}\\ \text{ambient}\\ \text{temperature}\end{array}\right\}}{2}$$

Variable 2.3: intermediate variable, DTL 3.

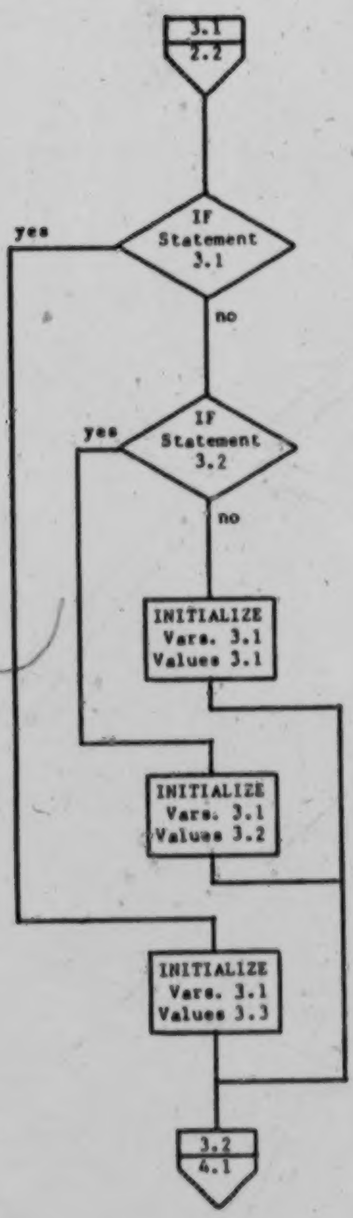
Equation 2.3:

$$\text{DTL 3} = \left\{\begin{array}{l}\text{temperature}\\ \text{difference}\\ \text{across the}\\ \text{air space}\end{array}\right\} \times \left\{\begin{array}{l}\text{average}\\ \text{temperature}\\ \text{of the}\\ \text{air cavity}\end{array}\right\}^{3}$$

Equation 2.4: $x = \log_{10} \{\text{DTL 3}\}$

Figure A4. Continued

AIRCAV 3


3.1
2.2
yes
IF Statement 3.1
no
yes
IF Statement 3.2
no
INITIALIZE Vars. 3.1 Values 3.1
INITIALIZE Vars. 3.1 Values 3.2
INITIALIZE Vars. 3.1 Values 3.3
3.2
4.1

Statement 3.1: $\left\{\begin{matrix}\text{heat flow}\\ \text{direction}\\ \text{index for}\\ \text{attic}\end{matrix}\right\} = \left\{\text{upward}\right\}$

Statement 3.2: DTL 3 $>$ 10.

Variables 3.1: values of A_0, A_1, A_2, and A_3 for calculation of resistance across the air space.

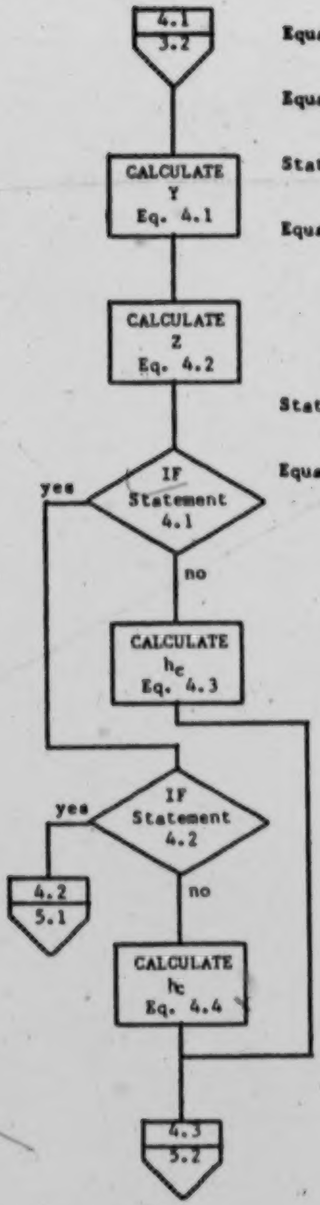
Values 3.1: $A_0 = -1.77$
$A_1 = 0.0$
$A_2 = 0.0$
$A_3 = 0.0$

Values 3.2: $A_0 = -1.745$
$A_1 = -0.0028$
$A_2 = 0.0029$
$A_3 = 0.0008$

Values 3.3: $A_0 = -1.5904$
$A_1 = 0.2824$
$A_2 = 0.0$
$A_3 = 0.0$

Figure A4. Continued

AIRCAV 4


4.1
3.2
CALCULATE
Y
Eq. 4.1
CALCULATE
Z
Eq. 4.2
IF
Statement
4.1
yes
no
CALCULATE
h_c
Eq. 4.3
IF
Statement
4.2
yes
no
4.2
5.1
CALCULATE
h_c
Eq. 4.4
4.3
5.2

Equation 4.1: $Y = A_0 + (A_1X) + (A_2X^2) + (A_3X^3)$

Equation 4.2: $Z = \exp(Y)$

Statement 4.1: $0.2 > Z > 0.3$

Equation 4.3:

$$h_c = \frac{Z \times \left\{1 + 0.00035 \times \left[\left(\begin{array}{c}\text{temperature}\\ \text{difference}\\ \text{across the}\\ \text{air space}\end{array}\right) - 50\right]\right\}}{\text{thickness of the air space}}$$

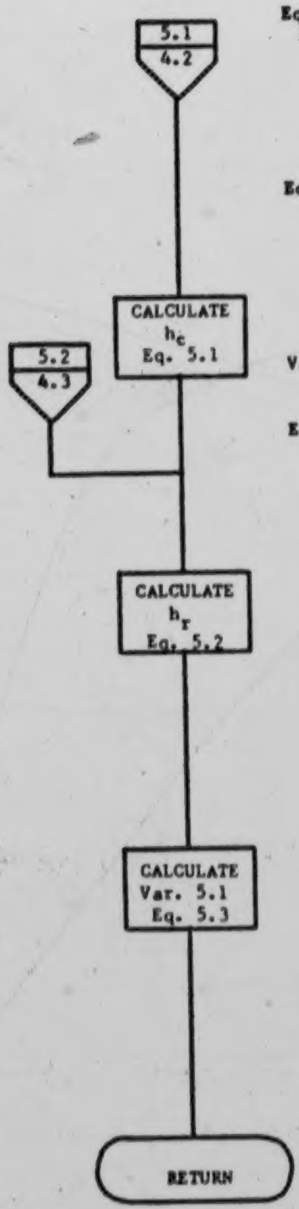
Statement 4.2: $Z < 0.2$

Equation 4.4:

$$h_c = \frac{Z \times \left\{1 - 0.001 \times \left[\left(\begin{array}{c}\text{temperature}\\ \text{difference}\\ \text{across the}\\ \text{air space}\end{array}\right) - 50\right]\right\}}{\text{thickness of the air space}}$$

Figure A4. Continued

AIRCAV 5



Equation 5.1:

$$h_c = \frac{Z \times \left\{ 1 + 0.0017 \times \left[\begin{pmatrix} \text{temperature} \\ \text{difference} \\ \text{across the} \\ \text{air space} \end{pmatrix} - 50 \right] \right\}}{\text{thickness of the air space}}$$

Equation 5.2:

$$h_r = 0.00686 \times \left[\frac{\left\{ \begin{matrix} \text{average} \\ \text{temperature} \\ \text{of the} \\ \text{air space} \end{matrix} \right\} + 460}{100} \right]^3$$

Variable 5.1: air cavity thermal resistance.

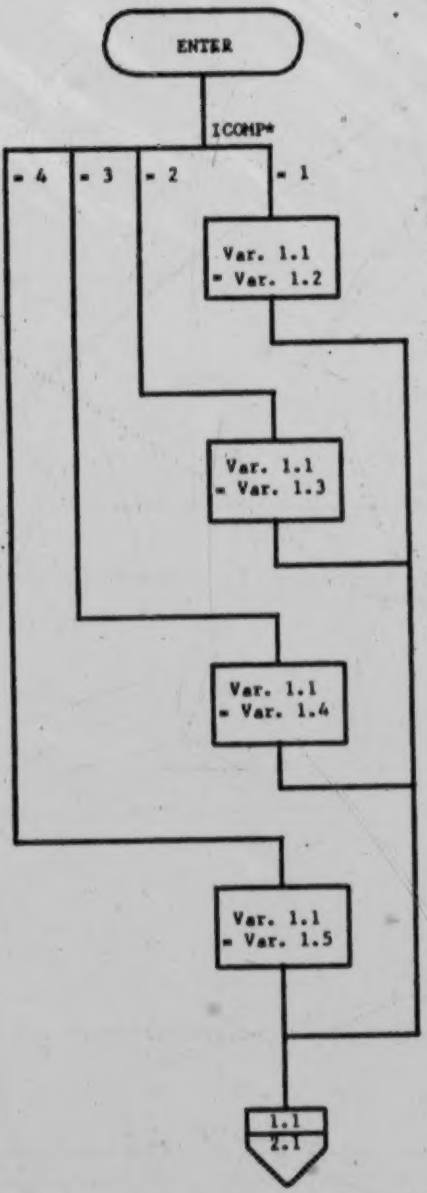
Equation 5.2:

$$\left\{ \begin{matrix} \text{air} \\ \text{cavity} \\ \text{thermal} \\ \text{resistance} \end{matrix} \right\} = \frac{1}{h_c + \left[\frac{1}{\frac{1}{\left\{ \begin{matrix} \text{emissivity} \\ \text{of the} \\ \text{upper} \\ \text{surface} \\ \text{facing} \\ \text{the air} \\ \text{cavity} \end{matrix} \right\}} + \frac{1}{\left\{ \begin{matrix} \text{emissivity} \\ \text{of the} \\ \text{lower} \\ \text{surface} \\ \text{facing} \\ \text{the air} \\ \text{cavity} \end{matrix} \right\}} - 1} \right] \times h_r}$$

Figure A5. Flow diagram for subroutine START.

START 1

START: An algorithm for determining convection, radiation and heat flux for each surface of a building component and then solving for outside and inside surface temperatures for the first seven hours of simulation.


ENTER
ICOMP*
= 4
= 3
= 2
= 1
Var. 1.1 = Var. 1.2
Var. 1.1 = Var. 1.3
Var. 1.1 = Var. 1.4
Var. 1.1 = Var. 1.5
1.1
2.1

*ICOMP = 1 for walls,
ICOMP = 2 for pitched roof,
ICOMP = 3 for horizontal roof, and
ICOMP = 4 for doors.

Variable 1.1: inside film conductance.

Variable 1.2: inside film conductance for walls.

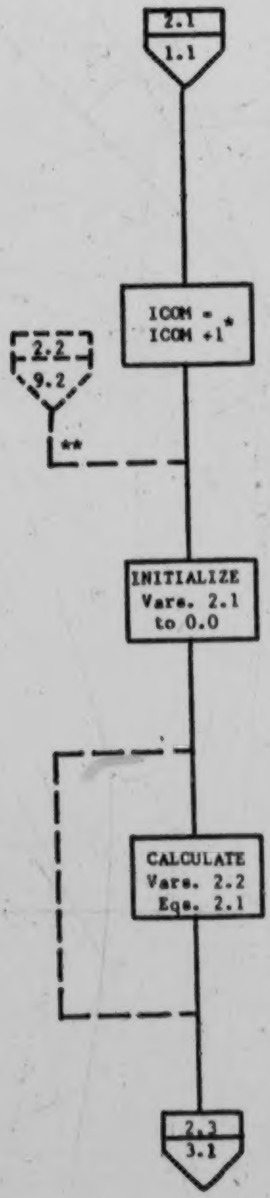
Variable 1.3: inside film conductance for pitched roof.

Variable 1.4: inside film conductance for horizontal roof.

Variable 1.5: inside film conductance for doors.

Figure A5. Continued

START 2



* ICOM = 1, ..., 11 as per MAIN, Note 9.2.

** for first 7 hours of simulation.

Variables 2.1: heat flux history, intermediate variable for calculation of radiation, convection and heat flux; heat flux; and shortwave and longwave radiation for both surfaces of the building component.

Variables 2.2: intermediate variables for calculation of heat flux and surface temperatures; SUM 1, SUM 2, SUM 3, SUM 4, SUM 5, and SUM 6.

Equation 2.1:

$$\text{SUM } 1 = \Sigma_{j=1}^{n} T_{o,\, t-j} A_j$$

$$\text{SUM } 2 = \Sigma_{j=1}^{n} T_{i,\, t-j} B_j$$

$$\text{SUM } 3 = \Sigma_{j=1}^{n} T_{i,\, t-j} C_j$$

$$\text{SUM } 4 = \Sigma_{j=1}^{n} T_{o,\, t-j} B_j$$

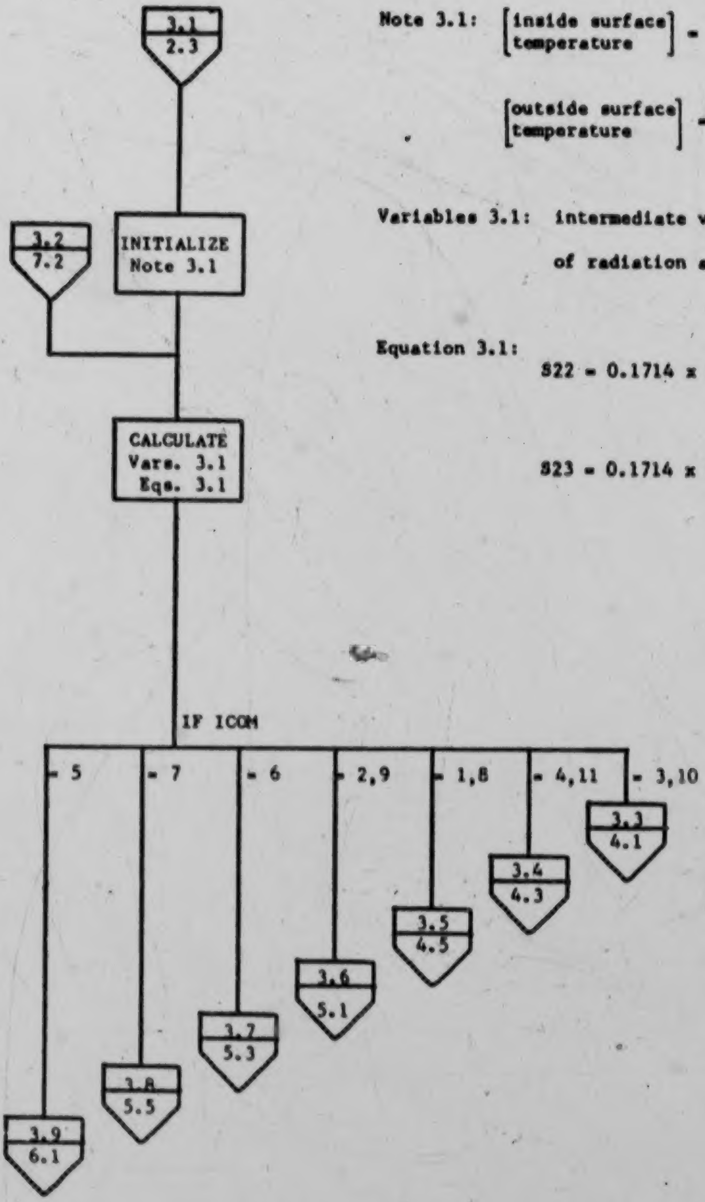
$$\text{SUM } 5 = \Sigma_{j=1}^{n} Q_{o,\, t-j} D_j$$

$$\text{SUM } 6 = \Sigma_{j=1}^{n} Q_{i,\, t-j} D_j$$

where $T_{o,\, t-j}$ and $T_{i,\, t-j}$ are the outside and inside surface temperature for time t-j; $Q_{o,\, t-j}$ and $Q_{i,\, t-j}$ are the outside and inside heat flux for time t-j; A_j, B_j, C_j and D_j are the z-transfer function coefficients that relate to the z-transforms of the surface temperatures and heat fluxes; and n refers to the number of z-trnasfer function coefficients that exist for the particular component.

Figure A5. Continued

START 3


3.1
2.3
3.2
7.2
INITIALIZE
Note 3.1
CALCULATE
Vars. 3.1
Eqs. 3.1
IF ICOM
= 5
= 7
= 6
= 2,9
= 1,8
= 4,11
= 3,10
3.3
4.1
3.4
4.3
3.5
4.5
3.6
5.1
3.7
5.3
3.8
5.5
3.9
6.1

Note 3.1: $\begin{bmatrix}\text{inside surface}\\ \text{temperature}\end{bmatrix} = \begin{bmatrix}\text{inside dry-bulb}\\ \text{temperature}\end{bmatrix}$

$\begin{bmatrix}\text{outside surface}\\ \text{temperature}\end{bmatrix} = 0.0$

Variables 3.1: intermediate variables for determination of radiation at each surface; S22 and S23.

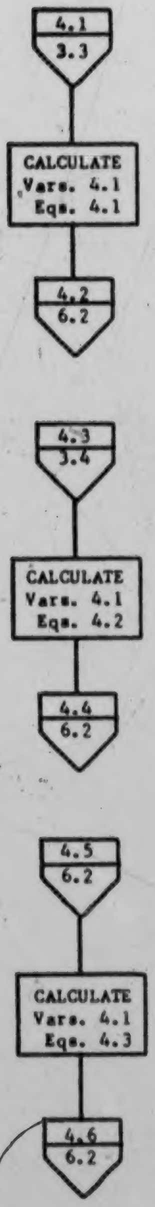
Equation 3.1:

$$S22 = 0.1714 \times 10^{-8} \times \left[460 + \begin{matrix}\text{outside}\\ \text{surface}\\ \text{temperature}\end{matrix}\right]^4$$

$$S23 = 0.1714 \times 10^{-8} \times \left[460 + \begin{matrix}\text{outside}\\ \text{temperature}\end{matrix}\right]^4$$

Figure A5. Continued

START 4



Variables 4.1: - radiation (longwave), R_t^*

- radiation absorbed by the surface (shortwave), S_t^*

* for outside surface at time, t

Equation 4.1:

$$R_t = \left\{\begin{matrix}\text{emissivity factor}\\ \text{for wall}\end{matrix}\right\} \times S22$$

$$S_t = \left\{\begin{matrix}\text{absorptivity factor}\\ \text{for wall}\end{matrix}\right\} \times \left\{\begin{matrix}\text{solar load on}\\ \text{east wall}\end{matrix}\right\} + \left\{\begin{matrix}\text{emissivity factor}\\ \text{for wall}\end{matrix}\right\} \times S23$$

Equations 4.2:

$$R_t = \left\{\begin{matrix}\text{emissivity factor}\\ \text{for wall}\end{matrix}\right\} \times S22$$

$$S_t = \left\{\begin{matrix}\text{absorptivity factor}\\ \text{for wall}\end{matrix}\right\} \times \left\{\begin{matrix}\text{solar load on}\\ \text{north wall}\end{matrix}\right\} + \left\{\begin{matrix}\text{emissivity factor}\\ \text{for wall}\end{matrix}\right\} \times S23$$

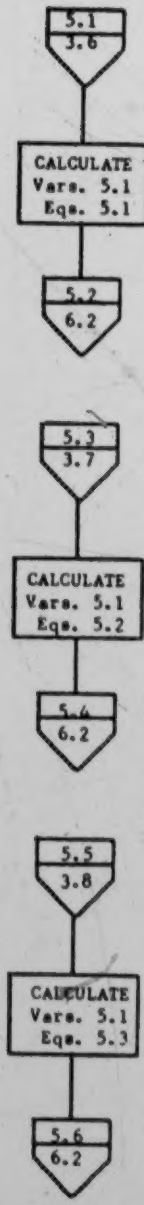
Equations 4.3:

$$R_t = \left\{\begin{matrix}\text{emissivity factor}\\ \text{for wall}\end{matrix}\right\} \times S22$$

$$S_t = \left\{\begin{matrix}\text{absorptivity factor}\\ \text{for wall}\end{matrix}\right\} \times \left\{\begin{matrix}\text{solar load on}\\ \text{south wall}\end{matrix}\right\} + \left\{\begin{matrix}\text{emissivity factor}\\ \text{for wall}\end{matrix}\right\} \times S23$$

Figure A5. Continued

START 5



Variables 5.1: - radiation (longwave), R_t^*

- radiation absorbed by the surface (shortwave), S_t^*

* for outside surface at time, t

Equations 5.1:

$$R_t = \left\{\begin{array}{l}\text{emissivity factor}\\ \text{for wall}\end{array}\right\} \times S22$$

$$S_t = \left\{\begin{array}{l}\text{absorptivity factor}\\ \text{for wall}\end{array}\right\} \times \left\{\begin{array}{l}\text{solar load on}\\ \text{west wall}\end{array}\right\} + \left\{\begin{array}{l}\text{emissivity factor}\\ \text{for wall}\end{array}\right\} \times S23$$

Equations 5.2:

$$R_t = \left\{\begin{array}{l}\text{emissivity factor}\\ \text{for roof}\end{array}\right\} \times S22$$

$$S_t = \left\{\begin{array}{l}\text{absorptivity factor}\\ \text{for roof}\end{array}\right\} \times \left\{\begin{array}{l}\text{solar load on}\\ \text{east roof slope}\end{array}\right\} + \left\{\begin{array}{l}\text{emissivity factor}\\ \text{for roof}\end{array}\right\} \times S23$$

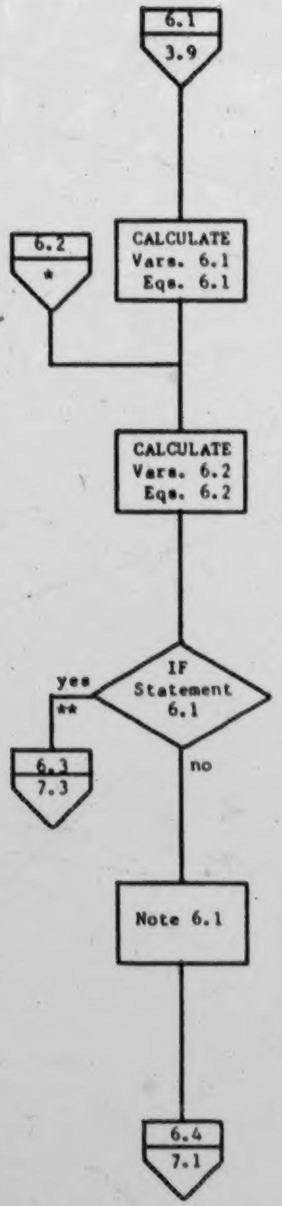
Equations 5.3:

$$R_t = \left\{\begin{array}{l}\text{emissivity factor}\\ \text{for roof}\end{array}\right\} \times S22$$

$$S_t = \left\{\begin{array}{l}\text{absorptivity factor}\\ \text{for roof}\end{array}\right\} \times \left\{\begin{array}{l}\text{solar load on}\\ \text{horizontal roof}\end{array}\right\} + \left\{\begin{array}{l}\text{emissivity factor}\\ \text{for roof}\end{array}\right\} \times S23$$

Figure A5. Continued

START 6



Variables 6.1: - radiation (longwave), R_t*

- radiation absorbed by the surface (shortwave), S_t*

* for outside surface at time, t

Equations 6.1:

$$R_t = \left\{\begin{array}{l}\text{emissivity factor}\\ \text{for roof}\end{array}\right\} \times S22$$

$$S_t = \left\{\begin{array}{l}\text{absorptivity factor}\\ \text{for roof}\end{array}\right\} \times \left\{\begin{array}{l}\text{solar load on}\\ \text{west roof slope}\end{array}\right\} + \left\{\begin{array}{l}\text{emissivity factor}\\ \text{for roof}\end{array}\right\} \times S23$$

* pages 4.2, 4.4, 4.6, 5.2, 5.4 and 5.6

Variable 6.2: outside surface temperature.

Equation 6.2:

$$\left\{\begin{array}{l}\text{calculated}\\ \text{outside}\\ \text{surface}\\ \text{temperature}\end{array}\right\} = \frac{\left[\begin{array}{l} R_t - \left\{\begin{array}{l}\text{outside}\\ \text{film}\\ \text{coefficient}\end{array} \times \begin{array}{l}\text{outside}\\ \text{temperature}\end{array}\right\} \\ - \left\{B_1 \times \begin{array}{c}\text{inside}\\ \text{surface}\\ \text{temperature}\end{array}\right\} \\ - S_t + SUM1 - SUM2 - SUM5 \end{array}\right]}{\left[- \left\{\begin{array}{l}\text{previous}\\ \text{outside}\\ \text{surface}\\ \text{temperature}\end{array}\right\} - A_1 \right]}$$

Statement 6.1:

$$\text{absolute value} \left/ \begin{array}{l}\text{outside}\\ \text{surface}\\ \text{temperature}\end{array} - \begin{array}{l}\text{previous}\\ \text{outside}\\ \text{surface}\\ \text{temperature}\end{array} \right/ \leq .05$$

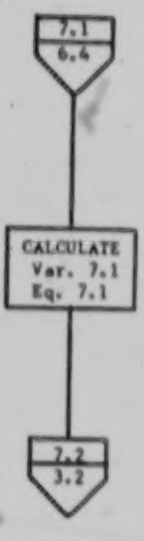
** iterative procedure

Note 6.1:

$$\left\{\begin{array}{l}\text{outside surface}\\ \text{temperature}\end{array}\right\} = \left\{\begin{array}{l}\text{calculated}\\ \text{outside surface}\\ \text{temperature}\end{array}\right\}$$

Figure A5. Continued

START 7



Variable 7.1: inside surface temperature.

Equation 7.2:

$$\left\{\begin{matrix}\text{inside}\\\text{surface}\\\text{temperature}\end{matrix}\right\} = \frac{\left[\begin{matrix}\left\{\begin{matrix}\text{longwave}\\\text{radiation}\\\text{at inside}\\\text{surface}\end{matrix}\right\} - \left\{\begin{matrix}\text{inside}\\\text{film}\\\text{coefficient}\end{matrix} \times \begin{matrix}\text{inside}\\\text{temperature}\end{matrix}\right\}\\ - \left\{B_1 \times \begin{matrix}\text{outside}\\\text{surface}\\\text{temperature}\end{matrix}\right\} - \left\{\begin{matrix}\text{shortwave}\\\text{radiation}\\\text{at inside}\\\text{surface}\end{matrix}\right\}\\ + \text{SUM6} + \text{SUM3} - \text{SUM4}\end{matrix}\right]}{\left[- \left\{\begin{matrix}\text{inside}\\\text{film}\\\text{coefficient}\end{matrix}\right\} - C_1\right]}$$

Variable 7.2: heat flux for inside surface.

Equation 7.2:

$$\left\{\begin{matrix}\text{heat flux}\\\text{for inside}\\\text{surface}\end{matrix}\right\} = \begin{matrix}- \text{SUM3} + \text{SUM4}\\ - C_1 \times \left\{\begin{matrix}\text{inside surface}\\\text{temperature}\end{matrix}\right\}\\ - B_1 \times \left\{\begin{matrix}\text{outside surface}\\\text{temperature}\end{matrix}\right\}\\ - \text{SUM6}\end{matrix}$$

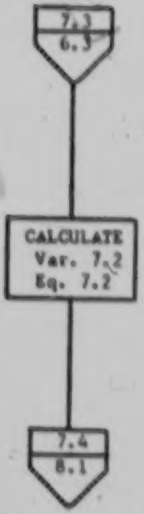
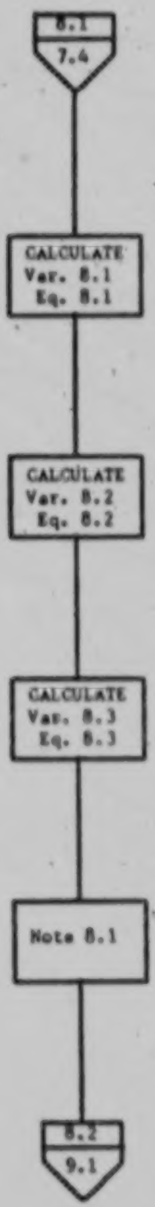


Figure A5. Continued

START 8



Variable 8.1: heat flux for outside surface.

Equation 8.1:

$$\begin{Bmatrix}\text{heat}\\ \text{flux for}\\ \text{outside}\\ \text{surface}\end{Bmatrix} = \text{SUM1} - \text{SUM2} + A_1 \times \begin{Bmatrix}\text{outside surface}\\ \text{temperature}\end{Bmatrix} - B_1 \times \begin{Bmatrix}\text{inside surface}\\ \text{temperature}\end{Bmatrix} - \text{SUM5}$$

Variable 8.2: convection at outside surface.

Equation 8.2:

$$\begin{Bmatrix}\text{convection}\\ \text{at outside}\\ \text{surface}\end{Bmatrix} = \begin{Bmatrix}\text{outside}\\ \text{film}\\ \text{coefficient}\end{Bmatrix} \times \begin{Bmatrix}\text{outside} & & \text{outside}\\ & - & \text{surface}\\ \text{temperature} & & \text{temperature}\end{Bmatrix}$$

Variable 8.3: convection at inside surface.

Equation 8.3:

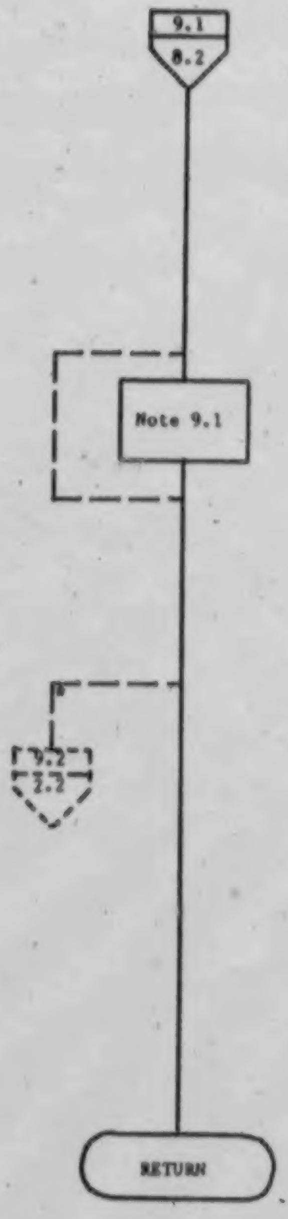
$$\begin{Bmatrix}\text{convection}\\ \text{at inside}\\ \text{surface}\end{Bmatrix} = \begin{Bmatrix}\text{inside}\\ \text{film}\\ \text{coefficient}\end{Bmatrix} \times \begin{Bmatrix}\text{inside} & & \text{inside}\\ & - & \text{surface}\\ \text{temperature} & & \text{temperature}\end{Bmatrix}$$

Note 8.1: transfer the following variables into the solar output matrix;

- longwave radiation (outside surface),
- shortwave radiation (outside surface),
- convection (outside surface),
- heat flux (outside surface),
- surface temperature (outside surface),
- surface temperature (inside surface),
- heat flux (inside surface),
- convection (inside surface), and
- dry-bulb temperature (inside).

Figure A5. Continued

START 9


9.1
8.2
Note 9.1
*
9.2
2.2
RETURN

Note 9.1: establish new temperature and heat flux history.

* for the first 7 hours of simulation.

Figure A6. Flow diagram for subroutine FLUX.

FLUX: An algorithm for determining convection, radiation and heat flux at each surface of a building component and then solving for the outside and inside temperature for time period beyond the first seven hours of simulation.

Subroutines FLUX is similar to subroutine START except that the temperature and flux histories do not have to be established prior to subroutine use. Pages FLUX 1, FLUX 4, FLUX 5, FLUX 6, FLUX 7 and FLUX 8 of FLUX are the same as the respective pages for START. The changes that are made on pages START 2, START 3, and START 9 to arrive at FLUX 2, FLUX 3 and FLUX 9 follow.

FLUX 2: - no initialization of heat flux history required.

- do-loop off-page connector 2.2 from 9.2 is not required.

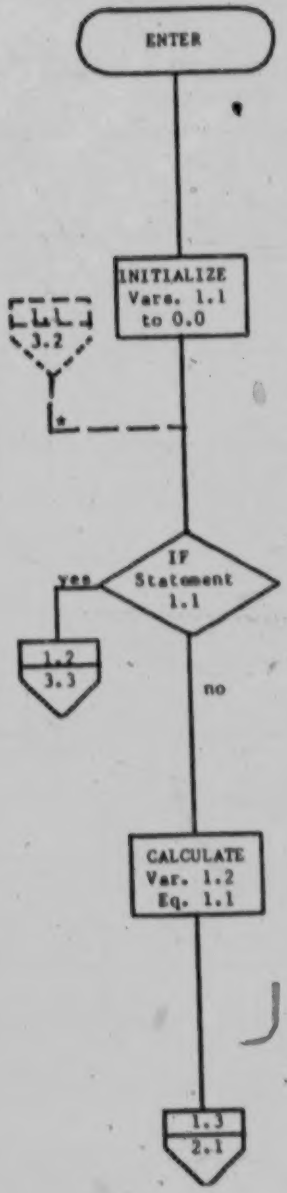
FLUX 3: - change in Note 3.1 - inside surface and outside surface temperatures are set as equal to the respective surface temperatures at time, t-1 (one hour previous).

FLUX 9: - page 9 is not required; return after page 8.

Figure A7. Flow diagram for subroutine HPROD.

HPROD 1

HPROD: An algorithm to calculate the sensible heat production and the moisture production of the confined animals. This algorithm applies to swine and must be altered for other livestock.



Variables 1.1: - total sensible heat production for all hogs of all weights, and
- total moisture production for all hogs of all weights.

Statement 1.1: $\left\{\begin{matrix}\text{average hog}\\ \text{weight of}\\ \text{group}\end{matrix}\right\} = 0.0$

Variable 1.2: total heat production per hog of certain weight.

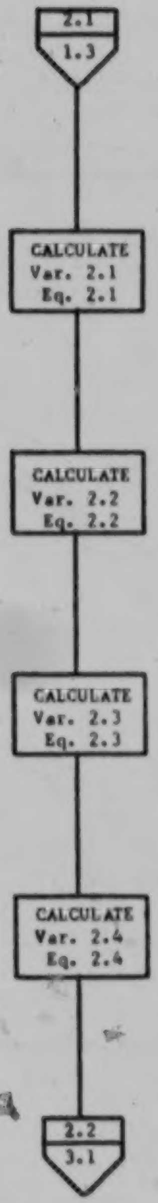
Equation 1.1:

$$\left\{\begin{matrix}\text{total heat}\\ \text{production}\\ \text{per hog of}\\ \text{a certain}\\ \text{weight}\end{matrix}\right\} = \text{Antilog}_{10}\left[\begin{matrix}2.477 + 0.34\,(\log_{10}(\text{hog weight}))\\ - 0.00577\,(\text{inside temperature})\\ + 0.148\,(\log_{10}(\text{hog weight}))^2\\ + 0.000071\,(\text{inside temperature})^2\\ - 0.00313\,(\text{inside temperature})\,(\log_{10}(\text{hog weight}))\end{matrix}\right]$$

* summation of a maximum of ten groups of hogs.

Figure A7. Continued

HPROD 2



Variable 2.1: moisture production per hog of a certain weight.

Equation 2.1:

$$\left\{\begin{array}{l}\text{moisture}\\ \text{production}\\ \text{per hog of}\\ \text{a certain}\\ \text{weight}\end{array}\right\} = \text{Antilog}_{10}\left[\begin{array}{l} -0.961 + 0.00291\,(\text{hog weight}) \\ -0.00785\,(\text{inside temperature}) \\ -0.0000146\,(\text{inside temperature}) \\ \quad(\text{hog weight}) \\ -0.0000029\,(\text{hog weight})^2 \\ +0.0001375\,(\text{inside temperature})^2 \end{array}\right] \times \left\{\begin{array}{l}\text{management factor for moisture}\\ \text{production}\end{array}\right\}$$

Variable 2.2: latent heat production per hog of a certain weight.

Equation 2.2:

$$\left\{\begin{array}{l}\text{latent heat}\\ \text{production}\\ \text{per hog of}\\ \text{a certain}\\ \text{weight}\end{array}\right\} = 1040\left\{\begin{array}{l}\text{moisture production}\\ \text{per hog of a certain}\\ \text{weight}\end{array}\right\}$$

Variable 2.3: sensible heat production per hog of a certain weight.

Equation 2.3:

$$\left\{\begin{array}{l}\text{sensible heat}\\ \text{production}\\ \text{per hog of a}\\ \text{certain weight}\end{array}\right\} = \left\{\begin{array}{lcl}\text{total heat} & & \text{latent heat}\\ \text{production} & & \text{production}\\ \text{per hog of} & - & \text{per hog of}\\ \text{a certain} & & \text{a certain}\\ \text{weight} & & \text{weight}\end{array}\right\} \times \left\{\begin{array}{l}\text{management}\\ \text{factor for}\\ \text{sensible}\\ \text{heat}\\ \text{production}\end{array}\right\}$$

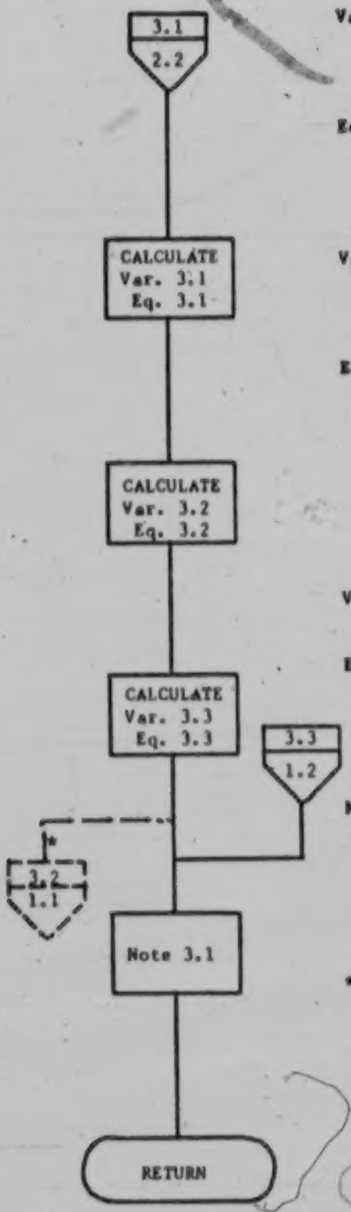
Variable 2.4: total moisture production for all hogs of a certain weight.

Equation 2.4:

$$\left\{\begin{array}{l}\text{total moisture}\\ \text{production for}\\ \text{all hogs of a}\\ \text{certain weight}\end{array}\right\} = \left\{\begin{array}{l}\text{moisture}\\ \text{production}\\ \text{per hog of}\\ \text{a certain}\\ \text{weight}\end{array}\right\} \times \left\{\begin{array}{l}\text{number of}\\ \text{hogs of}\\ \text{that}\\ \text{weight}\end{array}\right\}$$

Figure A7. Continued

HPROD 3



Variable 3.1: total sensible heat production of all hogs of a certain weight.

Equation 3.1:

$$\left\{\begin{array}{l}\text{total sensible}\\ \text{heat production}\\ \text{of all hogs of}\\ \text{a certain weight}\end{array}\right\} = \left\{\begin{array}{l}\text{sensible heat}\\ \text{production per}\\ \text{hog of a certain}\\ \text{weight}\end{array}\right\} \times \left\{\begin{array}{l}\text{number of}\\ \text{hogs of}\\ \text{that}\\ \text{weight}\end{array}\right\}$$

Variable 3.2: total sensible heat production of all confined hogs of all weights.

Equation 3.2:

$$\left\{\begin{array}{l}\text{total sensible}\\ \text{heat production}\\ \text{of all hogs of}\\ \text{all weights}\end{array}\right\} = \Sigma_{w=1}^{n} \left\{\begin{array}{l}\text{total sensilbe}\\ \text{heat production}\\ \text{of all hogs of}\\ \text{a certain weight}\end{array}\right\}_{w}$$

where w = weight of a group of hogs, and

n = number of hog groups

Variable 3.3: total moisture production of all hogs of all weights.

Equation 3.3:

$$\left\{\begin{array}{l}\text{total moisture}\\ \text{production of}\\ \text{all hogs of}\\ \text{all weights}\end{array}\right\} = \Sigma_{w=1}^{n} \left\{\begin{array}{l}\text{total moisture}\\ \text{production of}\\ \text{all hogs of a}\\ \text{certain weight}\end{array}\right\}_{w}$$

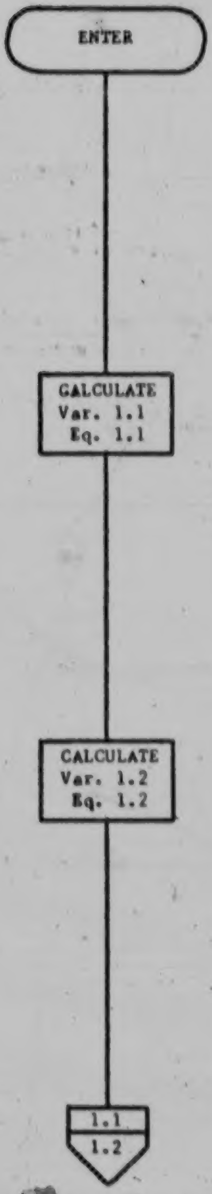
Note 3.1: assign new variable names to total sensible heat production and total moisture production of all confined hogs.

* summation of a maximum of ten groups of hogs.

Figure A8. Flow diagram for subroutine WALL.

WALL 1

WALL: An algorithm for determining the hourly heat transfer through the structural components of the confinement unit.



Variable 1.1: instantaneous rate of heat admission through the windows due to conduction or heat flow due to outdoor - indoor temperature difference.

Equation 1.1:

$$\begin{Bmatrix}\text{rate of heat}\\ \text{gain through}\\ \text{windows due}\\ \text{to conduction}\end{Bmatrix} = \begin{Bmatrix}\text{heat transfer}\\ \text{coefficient}\\ \text{of windows}\end{Bmatrix} \times \begin{Bmatrix}\text{outside}\\ \text{dry-bulb}\\ \text{temperature}\end{Bmatrix} - \begin{Bmatrix}\text{inside}\\ \text{dry-bulb}\\ \text{tempera-}\\ \text{ture}\end{Bmatrix}$$

Variable 1.2: total heat admission through the windows.

Equation 1.2:

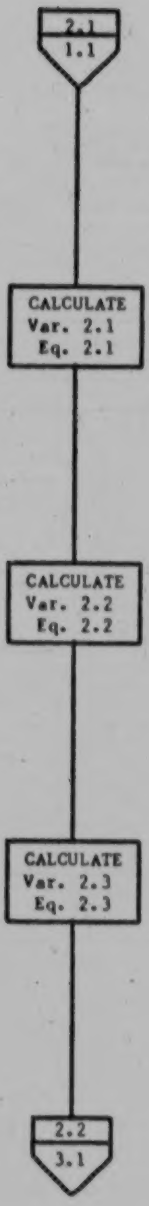
$$\begin{Bmatrix}\text{total heat}\\ \text{admission}\\ \text{through}\\ \text{the}\\ \text{windows}\end{Bmatrix} = \sum_{w=1}^{n} \left[\begin{Bmatrix}\text{shading}\\ \text{coefficient}\end{Bmatrix} \times \begin{Bmatrix}\text{solar heat}\\ \text{gain factor}\\ \text{for given}\\ \text{orientation}\end{Bmatrix}_w + \begin{Bmatrix}\text{rate of heat gain}\\ \text{through windows}\\ \text{due to conduction}\end{Bmatrix} \right] \times \begin{Bmatrix}\text{area of the windows}\\ \text{for a given}\\ \text{orientation}\end{Bmatrix}_w$$

where w = windows of a certain orientation, and

n = total number of orientations.

Figure A8. Continued

WALL 2



Variable 2.1: heat flow through the walls.

Equation 2.1:

$$\left\{\begin{matrix}\text{heat flow}\\ \text{through}\\ \text{the walls}\end{matrix}\right\} = \sum_{w=1}^{n} \left[\left\{\begin{matrix}\text{heat flux}\\ \text{at inside}\\ \text{wall surface}\end{matrix}\right\}_w \times \left\{\begin{matrix}\text{area} & & \text{area of}\\ \text{of} & - & \text{door and}\\ \text{wall} & & \text{windows}\end{matrix}\right\}_w\right]$$

where w = wall surface of a certain orientation, and

n = total number of orientations.

Variable 2.2: heat flow through the doors.

Equation 2.2:

$$\left\{\begin{matrix}\text{heat flow}\\ \text{through}\\ \text{the doors}\end{matrix}\right\} = \sum_{d=1}^{n} \left[\left\{\begin{matrix}\text{heat flux}\\ \text{at inside}\\ \text{door surface}\end{matrix}\right\}_d \times \left\{\begin{matrix}\text{area}\\ \text{of}\\ \text{doors}\end{matrix}\right\}_d\right]$$

where d = door surfaces of a certain orientation, and

n = total number of orientations.

Variable 2.3: heat flow through the roof slopes.

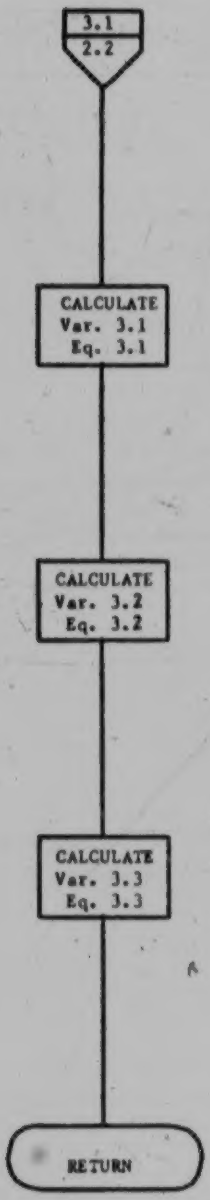
Equation 2.3:

$$\left\{\begin{matrix}\text{heat flow}\\ \text{through}\\ \text{the roof}\\ \text{slopes}\end{matrix}\right\} = \sum_{r=1}^{2} \left\{\begin{matrix}\text{heat flux}\\ \text{at inside}\\ \text{roof}\\ \text{surface}\end{matrix}\right\}_r \times \left\{\begin{matrix}\text{area of}\\ \text{roof}\\ \text{slope}\end{matrix}\right\}_r$$

where r = roof slope of a certain orientation

Figure A8. Continued

WALL 3



Variable 3.1: heat flow through horizontal roof.

Equation 3.1:

$$\left\{\begin{matrix}\text{heat flow}\\ \text{through}\\ \text{horizontal}\\ \text{roof}\end{matrix}\right\} = \left\{\begin{matrix}\text{heat flux}\\ \text{at inside}\\ \text{roof}\\ \text{surface}\end{matrix}\right\} \times \left\{\begin{matrix}\text{area of}\\ \text{horizontal}\\ \text{roof}\end{matrix}\right\}$$

Variable 3.2: heat flow through the floor.

Equation 3.2:

$$\left\{\begin{matrix}\text{heat flow}\\ \text{through}\\ \text{the floor}\end{matrix}\right\} = \left\{\begin{matrix}\text{perimeter}\\ \text{of the}\\ \text{floor}\end{matrix}\right\} \times 0.38 \left\{\begin{matrix}\text{outside}\\ \text{temperature}\end{matrix} - \begin{matrix}\text{inside}\\ \text{temperature}\end{matrix}\right\}$$

Variable 3.3: total heat flow through the structrual components.

Equation 3.3:

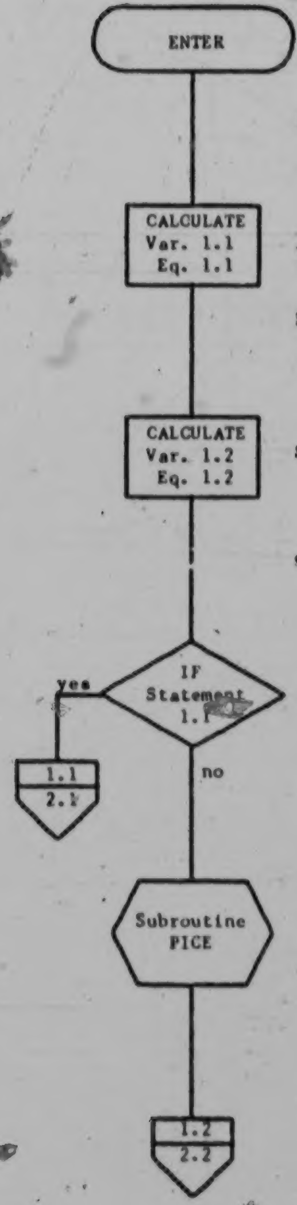
$$\left\{\begin{matrix}\text{total heat}\\ \text{flow through}\\ \text{the structural}\\ \text{components}\end{matrix}\right\} = \sum_{K=1}^{n} \left\{\begin{matrix}\text{heat flow}\\ \text{through}\\ \text{component}\end{matrix}\right\}_K$$

where K = walls, doors, floor, pitched roof, horizontal roof and windows.

Figure A9. Flow diagram for subroutine VENTIL.

VENTIL 1

VENTIL: An algorithm for determining the psychrometric properties of the air and for determining the ventilation rates required to remove heat and moisture loads.



Variable 1.1: enthalpy of saturated water vapor at inside temperature.

Equation 1.1:

$$\left\{\begin{array}{l}\text{enthalpy of}\\ \text{saturated}\\ \text{water vapor}\\ \text{at inside}\\ \text{temperature}\end{array}\right\} = 1061 + 0.444\left\{\begin{array}{l}\text{inside}\\ \text{dry-bulb}\\ \text{temperature}\end{array}\right\}$$

Variable 1.2: enthalpy of saturated water vapor at incoming temperature.

Equation 1.2:

$$\left\{\begin{array}{l}\text{enthalpy of}\\ \text{saturated}\\ \text{water vapor}\\ \text{at incoming}\\ \text{temperature}\end{array}\right\} = 1061 + 0.444\left\{\begin{array}{l}\text{incoming}\\ \text{dry-bulb}\\ \text{temperature}\end{array}\right\}$$

Statement 1.1:

$$\left\{\begin{array}{l}\text{incoming wet-}\\ \text{bulb}\\ \text{temperature}\end{array}\right\} > 32$$

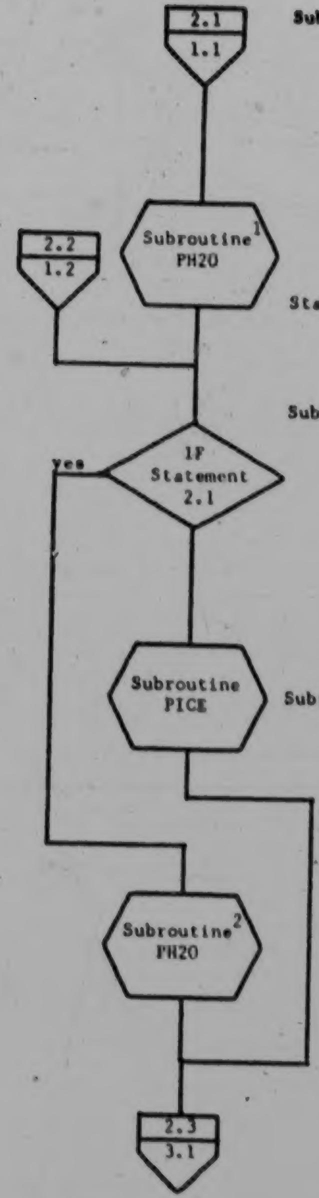
Subroutine PICE: An algorithm for determining the saturation pressure of air over ice.

parameters in: - time, and
- incoming wet-bulb temperatue

parameters out: - saturation pressure at incoming wet-bulb temperature

Figure A9. Continued

VENTIL 2


2.1
1.1
2.2
1.2
Subroutine^{1} PH20
yes
IF Statement 2.1
Subroutine PICE
Subroutine^{2} PH20
2.3
3.1

Subroutine^{1} PH20: An algorithm for determining the saturation pressure of air over liquid water.

parameters in: - time, and
- incoming wet-bulb temperature.

parameters out: - saturation pressure at incoming wet-bulb temperature.

Statement 2.1: $\left\{\begin{array}{l}\text{inside}\\ \text{dry bulb}\\ \text{temperature}\end{array}\right\} > 32$

Subroutine PICE: An algorithm for determining the saturation pressure of air over ice.

parameters in: - time, and
- inside dry-bulb temperature.

parameters out: - saturation pressure at inside dry-bulb temperature.

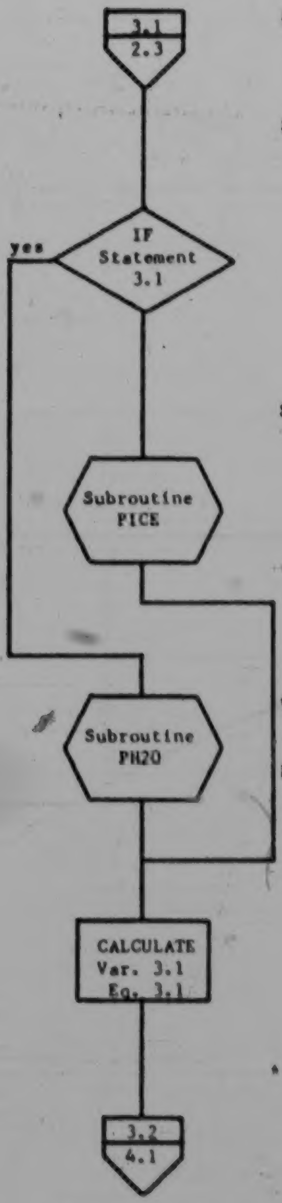
Subroutine^{2} PH20: An algorithm for determining the saturation pressure of air over liquid water.

parameters in: - time, and
- inside dry-bulb temperature.

parameters out: - saturation pressure at inside dry-bulb temperature.

Figure A9. Continued

VENTIL 3



Statement 3.1: $\left\{\begin{array}{l}\text{incoming}\\ \text{dry-bulb}\\ \text{temperature}\end{array}\right\} > 32$

Subroutine PICE: An algorithm for determining the saturation pressure of air over ice.

parameters in: - time, and
- incoming dry-bulb temperature

parameters out: - saturation pressure at incoming dry-bulb temperature.

Subroutine PH20: An algorithm for determining the saturation pressure of air over liquid water.

parameters in: - time, and
- incoming dry-bulb temperature.

parameters out: - saturation pressure at incoming dry-bulb temperature.

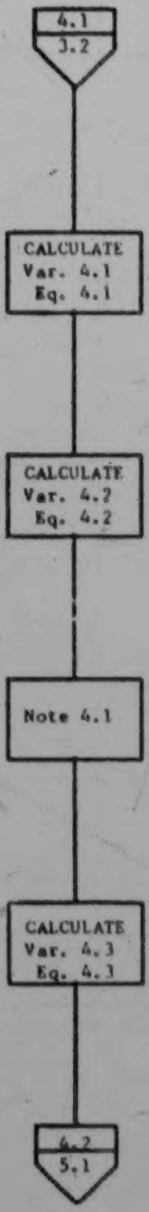
Variable 4.1: actual vapor pressure of incoming air.

Equation 4.1: $\left\{\begin{array}{l}\text{vapor pressure}\\ \text{of incoming air}\end{array}\right\} =$

$$\left[\begin{array}{l}\text{saturation}\\ \text{pressure at}\\ \text{incoming}\\ \text{wet-bulb}\\ \text{temperature}\end{array}\right] - \left[\begin{array}{l}\left\{\begin{array}{l}\text{barometric}\\ \text{pressure}\end{array} - \begin{array}{l}\text{saturation}\\ \text{pressure at}\\ \text{incoming}\\ \text{wet-bulb}\\ \text{temperature}\end{array}\right\}\\ \times\left\{\begin{array}{l}\text{incoming}\\ \text{dry-bulb}\\ \text{temperature}\end{array} - \begin{array}{l}\text{incoming}\\ \text{wet-bulb}\\ \text{temperature}\end{array}\right\}\\ \div\left\{2800 - 1.3\left[\begin{array}{l}\text{incoming}\\ \text{wet-bulb}\\ \text{temperature}\end{array}\right]\right\}\end{array}\right]$$

Figure A9. Continued

VENTIL 4



Variable 4.1: absolute humidity of incoming air, grains/lb.d.a.

Equation 4.1:

$$\left\{\begin{array}{l}\text{absolute}\\ \text{humidity}\\ \text{of incoming}\\ \text{air}\end{array}\right\} = \frac{4354 \times \left\{\begin{array}{l}\text{vapor pressure}\\ \text{of incoming air}\end{array}\right\}}{\left\{\begin{array}{l}\text{barometric}\\ \text{pressure}\end{array}\right\} - \left\{\begin{array}{l}\text{vapor pressure}\\ \text{of incoming air}\end{array}\right\}}$$

Variable 4.2: specific volume of incoming air.

Equation 4.2:

$$\left\{\begin{array}{l}\text{specific}\\ \text{volume of}\\ \text{incoming}\\ \text{air}\end{array}\right\} = \frac{0.754 \times \left\{\begin{array}{l}\text{incoming}\\ \text{dry-bulb}\\ \text{temperature} + 459.7\end{array}\right\} \times \left\{1 + \left[\frac{\begin{array}{l}\text{absolute}\\ \text{humidity}\\ \text{of incoming}\\ \text{air}\end{array}}{4360}\right]\right\}}{\text{barometric pressure}}$$

Note 4.1: convert absolute humidity of incoming air from grains per lb.d.a. to lb moisture per lb.d.a.

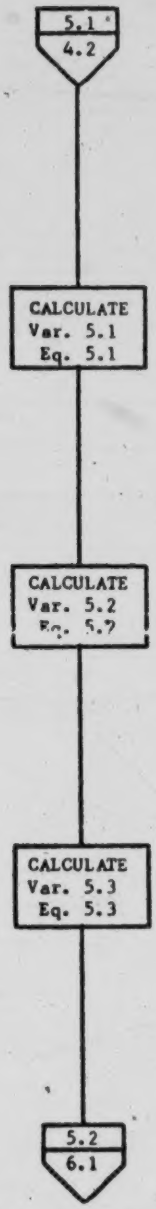
Variable 4.3: enthaply of incoming air at incoming temperature.

Equation 4.3:

$$\left\{\begin{array}{l}\text{enthalpy of}\\ \text{incoming air}\\ \text{at incoming}\\ \text{temperature}\end{array}\right\} = \left[0.24 \left\{\begin{array}{l}\text{incoming}\\ \text{dry-bulb}\\ \text{temperature}\end{array}\right\}\right] + \left[\left\{\begin{array}{l}\text{absolute}\\ \text{humidity}\\ \text{of incoming}\\ \text{air}\end{array}\right\} \times \left\{\begin{array}{l}\text{enthalpy of}\\ \text{saturated}\\ \text{water vapor}\\ \text{at incoming}\\ \text{temperature}\end{array}\right\}\right]$$

Figure A9. Continued

VENTIL 5



Variable 5.1: total sensible heat load within the confinement unit.

Equation 5.1:

$$\left\{\begin{array}{l}\text{total sensible}\\ \text{heat load}\\ \text{within the}\\ \text{confinement}\\ \text{unit}\end{array}\right\} = \left\{\begin{array}{l}\text{total heat}\\ \text{transfer}\\ \text{through the}\\ \text{structural}\\ \text{components}\end{array}\right\} + \left\{\begin{array}{l}\text{total sensible}\\ \text{heat production}\\ \text{of the}\\ \text{confined}\\ \text{animals}\end{array}\right\}$$

Variable 5.2: enthalpy of incoming air at inside temperature.

Equation 5.2:

$$\left\{\begin{array}{l}\text{enthalpy}\\ \text{of incoming}\\ \text{air at inside}\\ \text{temperature}\end{array}\right\} = \left[.24\left\{\begin{array}{l}\text{inside}\\ \text{dry-bulb}\\ \text{temperature}\end{array}\right\}\right] + \left[\left\{\begin{array}{l}\text{absolute}\\ \text{humidity}\\ \text{incoming}\\ \text{air}\end{array}\right\} \times \left\{\begin{array}{l}\text{enthalpy}\\ \text{of saturated}\\ \text{water vapor}\\ \text{at inside}\\ \text{temperature}\end{array}\right\}\right]$$

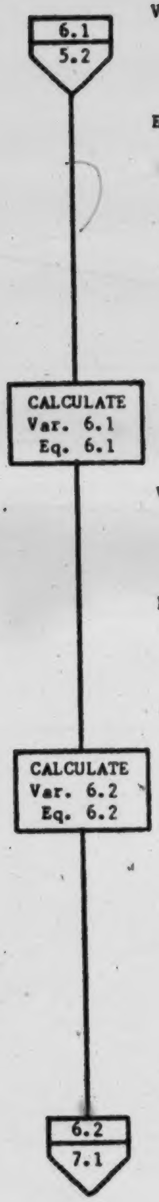
Variable 5.3: absolute humidity at saturation (inside conditions).

Equation 5.3:

$$\left\{\begin{array}{l}\text{absolute}\\ \text{humidity}\\ \text{at}\\ \text{saturation}\\ \text{(inside}\\ \text{conditions)}\end{array}\right\} = \frac{0.622 \times \left\{\begin{array}{l}\text{saturation pressure}\\ \text{at inside}\\ \text{dry-bulb}\\ \text{temperature}\end{array}\right\}}{\left\{\begin{array}{l}\text{barometric}\\ \text{pressure}\end{array}\right\} - \left\{\begin{array}{l}\text{saturation pressure}\\ \text{at inside}\\ \text{dry-bulb}\\ \text{temperature}\end{array}\right\}}$$

Figure A9. Continued

VENTIL 6



Variable 6.1: degree of saturation for ventilation rate required to remove moisture.

Equation 6.1:

$$\left\{\begin{matrix}\text{relative humidity}\\ \text{at ventilation}\\ \text{rate required to}\\ \text{remove moisture}\end{matrix}\right\} \times \left\{\begin{matrix}\text{barometric}\\ \text{pressure}\end{matrix}\right\}$$

$$\left\{\begin{matrix}\text{degree of}\\ \text{saturation}\\ \text{for}\\ \text{ventilation}\\ \text{rate required}\\ \text{to remove}\\ \text{moisture}\end{matrix}\right\} = \frac{\left\{\begin{matrix}\text{relative humidity}\\ \text{at ventilation}\\ \text{rate required to}\\ \text{remove moisture}\end{matrix}\right\} \times \left\{\begin{matrix}\text{saturation pressure}\\ \text{at inside}\\ \text{dry-bulb}\\ \text{temperature}\end{matrix}\right\}}{100.0 \times \left\{\begin{matrix}\text{barometric}\\ \text{pressure}\end{matrix}\right\} - \left\{\begin{matrix}\text{relative humidity}\\ \text{at ventilation}\\ \text{rate required to}\\ \text{remove moisture}\end{matrix}\right\} \times \left\{\begin{matrix}\text{saturation}\\ \text{pressure}\\ \text{at inside}\\ \text{dry-bulb}\\ \text{temperature}\end{matrix}\right\}}$$

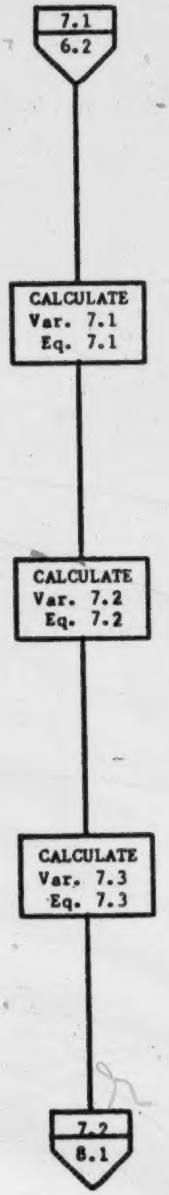
Variable 6.2: absolute humidity of inside air at the ventilation rate required to remove moisture.

Equation 6.2:

$$\left\{\begin{matrix}\text{absolute humidity}\\ \text{of inside air at}\\ \text{ventilation rate}\\ \text{required to remove}\\ \text{moisture}\end{matrix}\right\} = \left\{\begin{matrix}\text{degree of}\\ \text{saturation for}\\ \text{ventilation}\\ \text{rate required}\\ \text{to remove}\\ \text{moisture}\end{matrix}\right\} \times \left\{\begin{matrix}\text{absolute humidity}\\ \text{at saturation}\\ \text{(inside conditions)}\end{matrix}\right\}$$

Figure A9. Continued

VENTIL 7



Variable 7.1: ventilation rate required to remove moisture.

Equation 7.1:

$$\left\{\begin{array}{l}\text{ventilation}\\ \text{rate}\\ \text{required to}\\ \text{remove}\\ \text{moisture}\end{array}\right\} = \frac{\left\{\begin{array}{l}\text{total moisture}\\ \text{production}\end{array}\right\} \times \left\{\begin{array}{l}\text{specific volume}\\ \text{of incoming air}\end{array}\right\}}{60 \times \left\{\begin{array}{l}\text{absolute humidity}\\ \text{of inside air}\\ \text{at ventilation}\\ \text{rate required to}\\ \text{remove moisture}\end{array}\right\} - \left\{\begin{array}{l}\text{absolute}\\ \text{humidity of}\\ \text{incoming air}\end{array}\right\}}$$

Variable 7.2: ventilation rate required to remove heat load.

Equation 7.2:

$$\left\{\begin{array}{l}\text{ventilation}\\ \text{rate required}\\ \text{to remove}\\ \text{heat load}\end{array}\right\} = \frac{\left\{\begin{array}{l}\text{total sensible}\\ \text{heat load}\\ \text{within the}\\ \text{confinement}\\ \text{unit}\end{array}\right\} \times \left\{\begin{array}{l}\text{specific}\\ \text{volume}\\ \text{of the}\\ \text{incoming}\\ \text{air}\end{array}\right\}}{60 \times \left\{\begin{array}{l}\text{enthalpy of}\\ \text{incoming air}\\ \text{at inside}\\ \text{temperature}\end{array}\right\} - \left\{\begin{array}{l}\text{enthaply}\\ \text{incoming air}\\ \text{incoming}\\ \text{temperature}\end{array}\right\}}$$

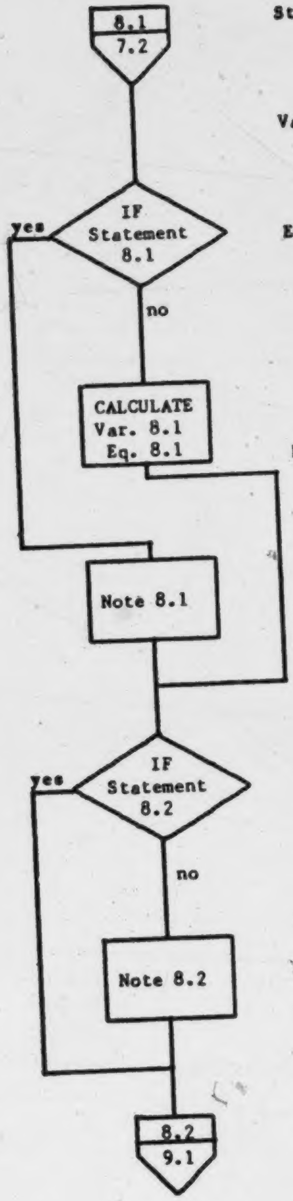
Variable 7.3: absolute humidity of the inside air at ventilation rate required to remove the heat load.

Equation 7.3:

$$\left\{\begin{array}{l}\text{absolute}\\ \text{humidity of}\\ \text{the inside}\\ \text{air at}\\ \text{ventilation}\\ \text{rate required}\\ \text{to remove}\\ \text{the heat load}\end{array}\right\} = \left\{\begin{array}{l}\text{absolute}\\ \text{humidity}\\ \text{of}\\ \text{incoming}\\ \text{air}\end{array}\right\} + \frac{\left\{\begin{array}{l}\text{total}\\ \text{moisture}\\ \text{production}\end{array}\right\} \times \left\{\begin{array}{l}\text{specific}\\ \text{volume of}\\ \text{incoming}\\ \text{air}\end{array}\right\}}{\left\{\begin{array}{l}\text{ventilation rate}\\ \text{required to}\\ \text{remove heat load}\end{array}\right\}}$$

Figure A9. Continued

VENTIL 8



Statement 8.1: $\left\{\begin{array}{l}\text{ventilation rate}\\ \text{required to}\\ \text{remove heat load}\end{array}\right\} \leq 0$

Variable 8.1: degree of saturation for ventilation rate required to remove heat load.

Equation 8.1:

$$\left\{\begin{array}{l}\text{degree of}\\ \text{saturation}\\ \text{for ventilation}\\ \text{rate required to}\\ \text{remove heat load}\end{array}\right\} = \frac{\left\{\begin{array}{l}\text{absolute humidity of}\\ \text{the inside air at}\\ \text{ventilation rate}\\ \text{required to remove}\\ \text{heat load}\end{array}\right\}}{\left\{\begin{array}{l}\text{absolute humidity at}\\ \text{saturation (inside}\\ \text{conditions)}\end{array}\right\}}$$

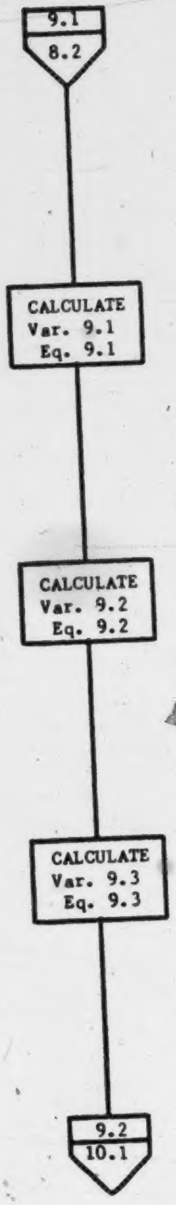
Note 8.1: $\left\{\begin{array}{l}\text{absolute humidity of}\\ \text{the inside air at}\\ \text{ventilation rate}\\ \text{required to remove}\\ \text{heat load}\end{array}\right\} = \left\{\begin{array}{l}\text{absolute}\\ \text{humidity at}\\ \text{saturation}\\ \text{(inside}\\ \text{conditions)}\end{array}\right\}$

Statement 8.2: $\left\{\begin{array}{l}\text{degree of}\\ \text{saturation for}\\ \text{ventilation}\\ \text{rate required}\\ \text{to remove}\\ \text{heat load}\end{array}\right\} \leq 1.0$

Note 8.2: $\left\{\begin{array}{l}\text{degree of saturation}\\ \text{for ventilation rate}\\ \text{required to remove}\\ \text{heat load}\end{array}\right\} = 1.0$

Figure A9. Continued

VENTIL 9



Variable 9.1: relative humidity for ventilation rate required to remove heat load.

Equation 9.1:

$$\left\{\begin{array}{l}\text{relative of}\\ \text{humidity for}\\ \text{ventilation}\\ \text{rate required}\\ \text{to remove}\\ \text{heat load}\end{array}\right\} = \frac{100.0 \times \left\{\begin{array}{l}\text{degree of saturation}\\ \text{for ventilation rate}\\ \text{required to remove}\\ \text{heat load}\end{array}\right\}}{1 - \left[\left\{1 - \left[\begin{array}{l}\text{degree of}\\ \text{saturation}\\ \text{for ventilation}\\ \text{rate required}\\ \text{to remove}\\ \text{heat load}\end{array}\right]\right\} \times \left\{\frac{\begin{array}{l}\text{saturation}\\ \text{pressure at}\\ \text{inside dry-}\\ \text{bulb}\\ \text{temperature}\end{array}}{\begin{array}{l}\text{barometric}\\ \text{pressure}\end{array}}\right\}\right]}$$

Variable 9.2: absolute humidity at saturation (incoming conditions).

Eqaution 9.2:

$$\left\{\begin{array}{l}\text{absolute}\\ \text{humidity}\\ \text{at saturation}\\ \text{(incoming}\\ \text{conditions)}\end{array}\right\} = \frac{0.622 \times \left\{\begin{array}{l}\text{saturation pressure}\\ \text{at incoming dry-bulb}\\ \text{temperature}\end{array}\right\}}{\left\{\begin{array}{l}\text{barometric}\\ \text{pressure}\end{array}\right\} - \left\{\begin{array}{l}\text{saturation pressure}\\ \text{at incoming dry-bulb}\\ \text{temperature}\end{array}\right\}}$$

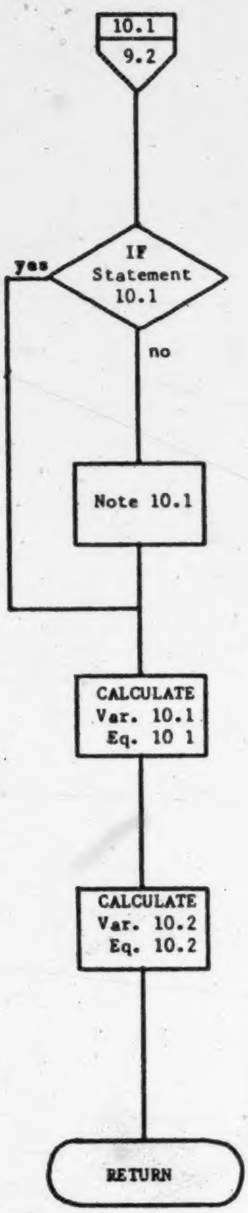
Variable 9.3: degree of saturation (incoming air).

Equation 9.3:

$$\left\{\begin{array}{l}\text{degree of}\\ \text{saturation}\\ \text{(incoming}\\ \text{air)}\end{array}\right\} = \frac{\begin{array}{l}\text{absolute humidity}\\ \text{of incoming air}\end{array}}{\begin{array}{l}\text{absolute humidity at}\\ \text{saturation (incoming conditions)}\end{array}}$$

Figure A9. Continued

VENTIL 10



Statement 10.1: $\left\{\begin{matrix}\text{degree of saturation}\\ \text{(incoming air)}\end{matrix}\right\} \leq 1.0$

Note 10.1: $\left\{\begin{matrix}\text{degree of saturation}\\ \text{(incoming air}\end{matrix}\right\} = 1.0$

Variable 10.1: incoming relative humidity.

Equation 10.1:

$$\left\{\begin{matrix}\text{incoming}\\ \text{relative}\\ \text{humidity}\end{matrix}\right\} = \frac{100.0 \times \left\{\begin{matrix}\text{degree of saturation}\\ \text{(incoming air}\end{matrix}\right\}}{1 - \left[\left\{1 - \left\{\begin{matrix}\text{degree}\\ \text{saturation}\\ \text{(incoming}\\ \text{air)}\end{matrix}\right\}\right\} \times \left\{\dfrac{\begin{matrix}\text{saturation pressure}\\ \text{at incoming dry-bulb}\\ \text{temperature}\end{matrix}}{\text{barometric pressure}}\right\}\right]}$$

Variable 10.2: heat load necessary to insure a ventilation rate required to remove moisture.

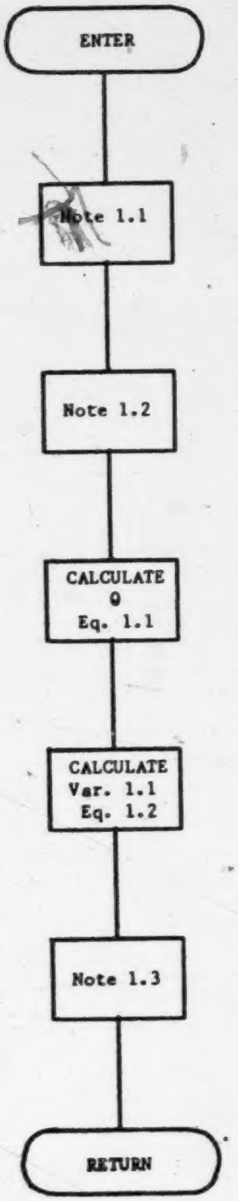
Equation 10.2:

$$\left\{\begin{matrix}\text{heat load}\\ \text{requirement}\end{matrix}\right\} = \left[\frac{60.0 \times \left[\begin{matrix}\text{ventilation rate required}\\ \text{to remove heat load.}\end{matrix}\right] \times \left[\left\{\begin{matrix}\text{enthalpy of}\\ \text{incoming air}\\ \text{at inside}\\ \text{temperature}\end{matrix}\right\} - \left\{\begin{matrix}\text{enthalpy of}\\ \text{incoming air}\\ \text{at incoming}\\ \text{temperature}\end{matrix}\right\}\right]}{\text{specific volume of incoming air}}\right]$$

$$- \left[\begin{matrix}\text{total sensible heat load within}\\ \text{the confinement unit}\end{matrix}\right]$$

Figure A10. Flow diagram for subroutine PICE.

PICE - An algorithm for determining the saturation vapor pressure of air over ice.



Note 1.1: convert temperature from fahrenheit to centigrade scale.

$$^\circ C = (^\circ F - 32) \times 5/9$$

Note 1.2: convert temperature to absolute temperature, Kelvin.

$$^\circ K = 273.16 + ^\circ C$$

Equation 1.1: $\theta = \frac{273.16}{^\circ K}$

Variable 1.1: saturation vapor pressure of air over ice, atmospheres.

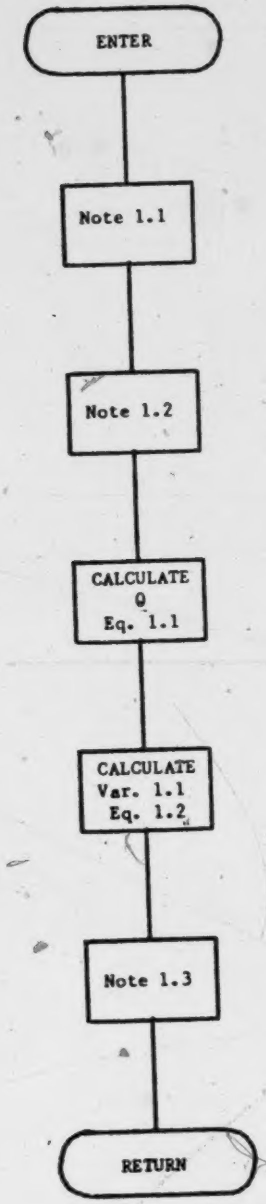
Equation 1.2: $$\begin{Bmatrix}\text{saturation}\\ \text{pressure}\\ \text{over ice}\end{Bmatrix} = \text{Antilog}_{10}\begin{bmatrix}-9.096936\ (\theta - 1)\\ -3.56654\ \log_{10}\ (\theta)\\ +0.876817\ (1 - \frac{1}{\theta})\\ -2.2195983\end{bmatrix}$$

Note 1.3: convert saturation vapor pressure from atmospheres to inches of mercury.

$$\text{in. Hg} = \text{atmospheres} \times 29.921$$

Figure A11. Flow diagram for subroutine PH2O

PH2O: An algorithm to determine the saturation vapor pressure of air over liquid water.



Note 1.1: convert temperature from fahrenheit to centigrade scale

$$°C = (°F - 32) \times 5/9$$

Note 1.2: convert temperature to absolute temperature, Kelvin

$$°K = 273.16 + °C$$

Equation 1.1: $\theta = \frac{273.16}{°K}$

Variable 1.1: saturation vapor pressure of air over liquid water, atmospheres.

Equation 1.2:

$$\left\{\begin{array}{l}\text{saturation}\\ \text{pressure}\\ \text{over liquid}\\ \text{water}\end{array}\right\} = \text{Antilog}_{10}\left[\begin{array}{l} 10.79586\,(1 - \theta) \\ + 5.02808 \log_{10}(\theta) \\ + 1.50474 \times 10^{-4} \\ \quad (1 - 10^{-8.29692(\frac{1}{\theta} - 1)}) \\ + 0.42873 \times 10^{-3} \\ \quad (10^{4.76955(1 - \theta)} - 1) \\ - 2.2195983 \end{array}\right]$$

Note 1.3: convert saturation vapor pressure from atmospheres to inches of mercury.

$$\text{in. Hg} = \text{atmospheres} \times 29.921$$

APPENDIX B: SOURCE PROGRAM LISTING.

B1. Main Program.

```
      DIMENSION  COEFI(3),   A1(120),A2(120),A3(120),B1(120),B2(120),B3
     1(120),C1(120),C2(120),C3(120),D1(120),D2(120),D3(120),TE(120),
     4POL5(100),AM1(150),AM2(150),TEM1(120),TEM2(120),TF(120),
     5G(120),Q(120),TW1(150),A(6),T(6),SA(250,100),OT(
     124),ST(99,100),OW(24),POL3(100),POL4(100),SH(120),SQ(120),
     7POL6(100),SE(120),SW(120),SN(120),SS(120),WIN(120),WAL(120),DOR(12
     20),FLO(120),ROF(120),ROOF(120),QSUM(120),SB(80,80),
     8SV(100,100),HOGWT(10),HOGS(10),SENS(120),WM(120),AZ(120),BZ(12
     10),CZ(120),DZ(120),DAY(5),RMONTH(5),YEAR(5),EQTIME(5),DECLIN(5),
     3VENT(150),C4(120),C5(120),RH1(120),SUP(120),SUMQ(120), RH2(120),
     4WALLA(7),WALLT(7),ISTOP(7),EA(7),EB(7),EC(7),HEATR(150),B(150),
     5ATTD(150),ATTW(150)
      COMMON A1,A2,A3,AZ,B1,B2,B3,BZ,C1,C2,C3,CZ,D1,D2,D3,DZ,
     1KXX,KXY,KXZ,KYX,AVH,SA
      REAL*8 A1,A2,A3,B1,B2,B3,C1,C2,C3,D1,D2,D3,SA,AZ,BZ,CZ,DZ,AVH
      REAL MGMT,MGMTS
      INTEGER O,KKK,LLL,JJJ,III,OOO,RRR,SSS,YYY,ITIMES,ITIME,SB,CCC
     1TTT,UUU
      DATA SB(1,1),SB(1,2),SB(1,3)/'CLOC','K TI','ME  '/
      DATA SB(2,1),SB(2,2),SB(2,3)/'SOLA','R TI','ME  '/
      DATA SB(3,1),SB(3,2),SB(3,3)/'ALTI','TUDE','    '/
      DATA SB(4,1),SB(4,2),SB(4,3)/'AZIM','UTH ','    '/
      DATA SB(5,1),SB(5,2),SB(5,3)/'D. I','NTEN','SITY'/
      DATA SB(6,1),SB(6,2),SB(6,3)/'DIRE','CT B','EAM '/
      DATA SB(7,1),SB(7,2),SB(7,3)/'SOLA','R LO','AD  '/
      DATA SB(8,1),SB(8,2),SB(8,3)/'S.H.','G.F.','    '/
      DATA SB(9,1),SB(9,2),SB(9,3)/'SOL.',' AIR','   O'/
      DATA SB(10,1),SB(10,2),SB(10,3)/'DRY ','BULB','   O'/
      DATA SB(11,1),SB(11,2),SB(11,3)/'WET ','BULB','   O'/
      DATA SB(12,1),SB(12,2),SB(12,3)/'LONG','. RA','D. O'/
      DATA SB(13,1),SB(13,2),SB(13,3)/'SHOR','T RA','D. O'/
      DATA SB(14,1),SB(14,2),SB(14,3)/'CONV','.   ','   O'/
      DATA SB(15,1),SB(15,2),SB(15,3)/'HEAT',' FLU','X  O'/
      DATA SB(16,1),SB(16,2),SB(16,3)/'SUR.',' TEM','P. O'/
      DATA SB(17,1),SB(17,2),SB(17,3)/'SUR.',' TEM','P. I'/
      DATA SB(18,1),SB(18,2),SB(18,3)/'HEAT',' FLU','X  I'/
      DATA SB(19,1),SB(19,2),SB(19,3)/'CONV','.   ','   I'/
      DATA SB(20,1),SB(20,2),SB(20,3)/'DRY ','BULB','   I'/
      READ(5,5008) TNT,AVH,EW,AW,AR,ER,UA,SC,RH
 5008 FORMAT(1X,F3.0,F3.0,6F3.2,F4.1)
      KKK=(TNT*24)+24
      READ(5,5044) (HEATR(I),I=1,KKK)
 5044 FORMAT(11F7.0)
      READ(5,1009) (HOGWT(I),I=1,10)
 1009 FORMAT(10F3.0)
      READ (5,1009) (HOGS(I),I=1,10)
      READ(5,1008) MGMT,MGMTS
 1008 FORMAT(2F4.2)
      READ(5,5045) (B(I),I=1,KKK)
 5045 FORMAT(16F5.2)
      READ(5,1011) AN,AEWA,ATWA,ASWA,AWWA,AEDO,ATDO,ASDO,AWDO,AEWI,ATWI,
     1ASWI,AWWI,AFLO,ARO1,ARO2,ARO3
 1011 FORMAT(17F4.0)
      READ(5,102) (VENT(I),I=1,KKK)
  102 FORMAT(11F7.0)
      READ(5,222) ERROR
  222 FORMAT(F6.2)
```

B1. Continued

```
      READ(5,21) COEF1,COEFI(1),COEFI(2),COEFI(3),EE1,EE2
   21 FORMAT(6F4.2)
      READ(5,400) IATTIC
  400 FORMAT(I3)
      DO 404 I=1,KKK
      ATTD(I)=0.0
      ATTW(I)=0.0
  404 CONTINUE
      IF (IATTIC.EQ.0) GO TO 401
      READ(5,402) (ATTD(I),I=1,KKK)
      READ(5,402) (ATTW(I),I=1,KKK)
  402 FORMAT(12F6.1)
  401 CALL SOLAR(ET,DECL,PLAT,PLONG,TZN,DST,TNT,LO,CA,TX,
     1DAY,RMONTH,YEAR,EQTIME,DECLIN,WALLT,WALLA,EA,EB,EC)
      DO 910 I=1,20
      A1(I)=0
      A2(I)=0
      A3(I)=0
      AZ(I)=0
      B1(I)=0
      B2(I)=0
      B3(I)=0
      BZ(I)=0
      C1(I)=0
      C2(I)=0
      C3(I)=0
      CZ(I)=0
      D1(I)=0
      D2(I)=0
      D3(I)=0
      DZ(I)=0
  910 CONTINUE
      DO 5020 K=1,KKK
      AM1(K)=SA(10,K)
      TW1(K)=SA(11,K)
      IF (IATTIC.EQ.1) GO TO 410
      IF(AM1(K).LT.60.0) AM2(K)=65.0
      IF(AM1(K).GE.60.0) AM2(K)=AM1(K)+5.0
      GO TO 411
  410 IF (ATTD(K).LT.60.0) AM2(K)=65.0
      IF (ATTD(K).GE.60.0) AM2(K)=ATTD(K)+5.0
  411 SA(20,K)=AM2(K)
 5020 CONTINUE
      CALL NAMEA1(EE1,EE2)
      DO 583 M=1,KKK
      TTT=0
      UUU=0
      CCC=0
  670 IZ=12
      ICOMP=1
      ICOM=0
      DO 121 I=1,KXX
      POL3(I)=A1(I)
      POL4(I)=A2(I)
      POL5(I)=A3(I)
      POL6(I)=AZ(I)
  121 CONTINUE
  584 IF (M.GT.7) GO TO 999
      TEP2=AM2(1)
      DO 122 I=1,KKK
```

B1. Continued

```
      TEM1(I)=SA(IZ-2,I)
      TEM2(I)=AM2(I)
  122 CONTINUE
      CALL START(ICOMP,ICON,POL3,POL4,POL5,POL6,TEM1,TEM2,TEP2,
     1AM1,AM2,EW,AW,AR,ER,COEF1,IZ,COEFI)
      GO TO 998
  999 CALL FLUX(M,ICOMP,ICON,POL3,POL4,POL5,POL6,
     1AM1,AM2,EW,AW,AR,ER,COEF1,IZ,COEFI)
  998 IZ=IZ+20
  821 GO TO (584,584,584,585,584,586,587,584,584,584,570),ICON
  585 DO 127 I=1,KXY
      POL3(I)=B1(I)
      POL4(I)=B2(I)
      POL5(I)=B3(I)
      POL6(I)=BZ(I)
  127 CONTINUE
      ICOMP=2
      GO TO 584
  586 DO 126 I=1,KXZ
      POL3(I)=C1(I)
      POL4(I)=C2(I)
      POL5(I)=C3(I)
      POL6(I)=CZ(I)
  126 CONTINUE
      ICOMP=3
      GO TO 584
  587 DO 125 I=1,KYX
      POL3(I)=D1(I)
      POL4(I)=D2(I)
      POL5(I)=D3(I)
      POL6(I)=DZ(I)
  125 CONTINUE
      ICOMP=4
      GO TO 584
  570 CALL WALL(M,UA,AM1,AM2,SC,AEWA,ATWA,ASWA,AWWA,AEDO,ATDO,
     1ASDO,AWDO,AEWI,ATWI,ASWI,AFLO,ARO1,ARO2,ARO3,WAL,DOR,FLO,ROOF,ROF,
     2WIN,QSUM)
      CALL HPROD(HOGWT,HOGS,MGMT,M,AM2,Q,G,MGMTS)
      WM(M)=G(M)
      SENS(M)=Q(M)+HEATR(M)
      IF (IATTIC.EQ.0) GO TO 403
      IF (CCC.EQ.1) GO TO 403
      AM1(M)=ATTD(M)
      TW1(M)=ATTW(M)
  403 CALL VENTIL(M,AM2,AM1,TW1,B,QSUM,
     1SENS,WM,RH,C4,C5,RH1,SUP,SUMQ,RH2)
      OUT=C5(M)-VENT(M)
      PERC=ABS(OUT/VENT(M))
      IF (PERC.GT.0.75.AND.RH2(M).GT.50.0.AND.AM2(M).LT.75.) GO TO 8000
      IF (PERC.GT.0.50.AND.RH2(M).GT.50.0.AND.AM2(M).LT.75.) GO TO 8001
      IF (PERC.GT.0.25.AND.RH2(M).GT.50.0.AND.AM2(M).LT.75.) GO TO 8002
      IF (PERC.GT.0.15.AND.RH2(M).GT.50.0.AND.AM2(M).LT.75.) GO TO 8003
      CHANGE=0.1
      GO TO 8004
 8000 CHANGE=3.0
      GO TO 8004
 8001 CHANGE=1.5
      GO TO 8004
 8002 CHANGE=0.5
      GO TO 8004
```

B1. Continued

```
 8003 CHANGE=0.2
 8004 CHECK=VENT(M)*ERROR
      DIFF2=C5(M)-VENT(M)
      IF (TTT.EQ.1.AND.UUU.EQ.1) GO TO 583
      IF (ABS(DIFF2).LE.CHECK) GO TO 583
      IF (DIFF2.GT.0.0) GO TO 668
  663 AM2(M)=AM2(M)-CHANGE
      TTT=1
      CCC=1
      GO TO 670
  668 AM2(M)=AM2(M)+CHANGE
      UUU=1
      CCC=1
      GO TO 670
  583 CONTINUE
      MM=1
      RRR=1
      SSS=20
      ICNT=0
      ITIMES=TNT+1
      DO 9010 YYY=1,ITIMES
      DO 652 NNN=1,7
      ITIME=1
 9011 WRITE(6,195) DAY(ICNT),RMONTH(ICNT),YEAR(ICNT),
     1PLAT,PLONG,TZN,DST,LO,CA,TX
  195 FORMAT('1',///////
     1           'DATA FOR',3A4,' LATITUDE =',F7.2,' LONGITUDE =',F7.2,'
     1   TIME ZONE =', F3.0,'  DST=', F3.0,'     LOCATION    ',3A4)
      WRITE(6,105) EQTIME(ICNT),DECLIN(ICNT)
  105 FORMAT('0','EQUATION OF TIME =',F8.3,'    DECLINATION =', F8.3)
      WRITE(6,295) EA(NNN),EB(NNN),EC(NNN),WALLT(NNN),WALLA(NNN)
  295 FORMAT('0',3A4,' SURFACE TILT =',F7.2,'  SURFACE AZIMUTH =',F7.2)
      O=1
      L=MM+1
      DO 1202 I=MM,L
      WRITE(6,1203) (SB(O,J),J=1,3),(SA(I,J),J=RRR,SSS)
 1203 FORMAT('0',3A4,20F6.2)
      O=O+1
 1202 CONTINUE
      LL=L+1
      II=LL+17
      DO 1204 I=LL,II
      WRITE(6,1205)(SB(O,J),J=1,3),(SA(I,J),J=RRR,SSS)
 1205 FORMAT('0',3A4,20F6.1)
      O=O+1
 1204 CONTINUE
      IF (ITIME.EQ.2) GO TO 9015
      MM=II-19
      RRR=RRR+20
      SSS=SSS+4
      ITIME=2
      GO TO 9011
 9015 MM=MM+20
      RRR=RRR-20
      SSS=SSS-4
  652 CONTINUE
      MM=1
      ICNT=ICNT+1
      RRR=RRR+24
      SSS=SSS+24
```

B1. Continued

```
 9010 CONTINUE
      WRITE(6,558)
  558 FORMAT(5X,'                        ')
      WRITE(6,558)
      WRITE(6,558)
      WRITE(6,6000)
 6000 FORMAT('0','AREAS',3X,'AN',2X,'EWAL',2X,'NWAL',2X,'SWAL',2X,'WWAL'
     1,2X,'EDOR',2X,'NDOR',2X,'SDOR',2X,'WDOR',2X,'EWIN',2X,'NWIN',2X,'S
     2WIN',2X,'WWIN',2X, 'FLOR',2X,'NROF',2X,'SROF',2X,'HROF')
      WRITE(6,558)
      WRITE(6,917) AN,AEWA,ATWA,ASWA,AWWA,AEDO,ATDO,ASDO,AWDO,AEWI,ATWI,
     1ASWI,AWWI,AFLO,ARO1,ARO2,ARO3
  917 FORMAT(5X,17F6.0)
      WRITE(6,558)
      WRITE(6,558)
      WRITE(6,6001)
 6001 FORMAT('0',35X,'HOURLY HEAT FLOWS THROUGH THE STRUCTURAL COMPONENT
     1S'//       28X,'WALLS',5X,'DOORS',5X,'FLOOR',2X,'HOR.ROOF',2X,'PIT
     1.ROOF',3X,'WINDOWS',5X,'TOTAL',1X,'HR')
      WRITE(6,558)
      DO 101 M=1,KKK
      WRITE(6,3012) WAL(M),DOR(M),FLO(M),ROOF(M),ROF(M),WIN(M),QSUM(M),M
 3012 FORMAT(24X,7F10.2,I3)
  101 CONTINUE
      WRITE(6,6003)
 6003 FORMAT('1',25X,'HOURLY VENTILATION CRITERIA CALCULATED FOR THE MOD
     1EL HOG BARN'//3X,'VENT.(IN)',5X,    'VENT.M',3X,'RH.M',1X,'VENT.H'
     1,3X,'RH.H',3X,'SUPL.H',4X,'TOTAL',4X,'AN+H',2X,'T.O',3X,'T.I',
     22X,'WB.O',5X,'M',3X,'HR',3X,'RH.O')
      WRITE(6,558)
      DO 701 M=1,KKK
      WRITE(6,654) VENT(M),C4(M),RH,C5(M),RH1(M),SUP(M),SUMQ(M),
     1SENS(M),AM1(M),AM2(M),TW1(M),WM(M),M,RH2(M)
  654 FORMAT(2X,F9.0,3X,F9.0,F7.1,F7.0,F7.1,3F9.0,4F6.1,I3,F7.1)
  701 CONTINUE
      CALL EXIT
      STOP
      END
```

B2. Subroutine SOLAR.

```
      SUBROUTINE SOLAR(ET.DECL.PLAT.PLONG.TZN.DST.TNT.LO.CA.
     1TX.DAY.RMONTH.YEAR.EQTIME.DECLIN.WALLT.WALLA.EA.EB.EC)
      DIMENSION AOUT(6).T(6).OW(24).OT(24).ST(99.100).AIN(6).
     1DAY(5).RMONTH(5).YEAR(5).EQTIME(5).DECLIN(5).
     2WALLT(7).WALLA(7).ISTOP(7).EA(7).EB(7).EC(7).TC(24)
      DOUBLE PRECISION SA(250.100).AVH.A1(120).A2(120).A3(120).AZ(120).
     1B1(120).B2(120).B3(120).BZ(120).C1(120).C2(120).C3(120).CZ(120).
     1D1(120).D2(120).D3(120).DZ(120)
      COMMON A1.A2.A3.AZ.B1.B2.B3.BZ.C1.C2.C3.CZ.D1.D2.D3.DZ.
     1KXX.KXY.KXZ.KYX.AVH.SA
      INTEGER CT
      REAL NII.NIO
      ICNT=0
      READ(5.85) (AIN(J).J=1.6.1)
      READ(5.85) (AOUT(J).J=1.6.1)
      READ(5.85) (T(J).J=1.6.1)
   85 FORMAT(6F10.5)
      READ(5.5) PLAT.PLONG.TZN.DST.LO.CA.TX
    5 FORMAT(2F7.2.2F3.0.3A4)
      DO 1105 I=1.7
      READ(5.25) WALLT(I).WALLA(I).ISTOP(I).EA(I).EB(I).EC(I)
   25 FORMAT(2F7.2.I3.2X.3A4)
 1105 CONTINUE
 9999 MM=1
      ADDIN = 0.
      ADDOUT = 0.
      TDD = 0.
      DO 100 J=1.6.1
      S = FLOAT(J)- 1.0
      TDD = T(J)/(S+2.0) + TDD
      ADDOUT = AOUT(J) / (S + 2.0) + ADDOUT
  100 ADDIN = AIN(J) /(S + 2.0)   + ADDIN
      TD = 2.0 * TDD
      ADIN = 2.0 * ADDIN
      ADOUT= 2.0 * ADDOUT
      READ(5.95) D. X. U. Z
   95 FORMAT(F5.0. 3A4)
      DAY(ICNT)=X
      RMONTH(ICNT)=U
      YEAR(ICNT)=Z
      READ(5.15) CN.CT.R.ARO.HO.NII.NIO
   15 FORMAT(F4.1.I1.F5.2.4F4.2)
      READ(5.60) (TC(I).I=1.24.1)
   60 FORMAT(24F2.0)
      READ(5.35)(OT(I). I=1.24.1)
   35 FORMAT(12F5.1)
      READ(5.36) (OW(I).I=1.24)
   36 FORMAT(12F5.1)
      W = 6.2832/366.0
      ET=-0.0002 +0.4197*COS(W*D) -3.2265*COS(2.0*W*D) -0.0903*COS(3.0*W
     1*D) -7.3509*SIN(W*D) -9.3912*SIN(2.0*W*D) -0.3361*SIN(3.0*W*D)
      EQTIME(ICNT)=ET
      DECL= 0.302 -22.93*COS(W*D) -0.229*COS(2.0*W*D) -0.243*COS(3.0*W*D
     1) +3.851*SIN(W*D) +0.002*SIN(2.0*W*D) -0.055*SIN(3.0*W*D)
      DECLIN(ICNT)=DECL
      AA=368.44-24.52*COS(W*D)-1.14*COS(2.0*W*D)-1.090*COS(3.0*W
     1*D)+0.5800*SIN(W*D)-0.1800*SIN(2.0*W*D)+0.2800*SIN(3.0*W*D)
      B=0.1717-0.0344*COS(W*D)+0.0032*COS(2.0*W*D)+0.0024*COS(3.0*W
```

B2. Continued

```
     2*D)-0.0043*SIN(W*D)+0.0000*SIN(2.0*W*D)-0.0008*SIN(3.0*W*D)
      C=0.0905-0.0410*COS(W*D)+0.0073*COS(2.0*W*D)+0.0015*COS(3.0*W
     3*D)-0.0034*SIN(W*D)+0.0004*SIN(2.0*W*D)-0.0006*SIN(3.0*W*D)
      DO 2100 IJK=1,7
      DO 1400 I=1,99
      DO 1200 J=1,100
      ST(I,J)=0.0
 1200 CONTINUE
 1400 CONTINUE
      DO 1100 K=1,24
      TIME = FLOAT(K)
      ST(22,K) =OT(K)
      ST(24,K)=OW(K)
      ST(1,K) = TIME
      BSTEP = -TAN(PLAT/57.296)
      HHSUN = ARCOS(BSTEP*TAN(DECL/57.296))
      HSUN = HHSUN * 57.296
      HAD = 15.0*(TIME - 12.0 + TZN + (ET/60.) - DST) - PLONG
      IF(ABS(HAD) - ABS(HSUN))51,51,1101
 1101 ST(23,K)=OT(K)
      GO TO 1100
   51 HA = (HAD/57.296)
      Y=HHSUN*(12.0/3.1416)
      SRT=12.0-Y-(ET/60.)-TZN+DST+PLONG/15.0
      SST=24.-SRT
      ST(2,K) = HAD/15.
      DEC = DECL/57.296
      BLAT = PLAT/57.296
      COSZ=SIN(BLAT)*SIN(DEC) + COS(BLAT)*COS(DEC)*COS(HA)
      ST(3,K) = ARCOS(COSZ) * 57.296
      COSW = COS(DEC) * SIN(HA)
      ST(4,K) = ARCOS(COSW)*57.296
      COSSS = (1.0 - (COSZ)**2 - (COSW)**2)**0.5
      SALT = ARSIN(COSZ)
      ST(6,K) = SALT * 57.296
      IF (CT.EQ.0.AND.ST(6,K).LE.45.0) GO TO 101
      IF (CT.EQ.0.AND.ST(6,K).GT.45.0) GO TO 102
      IF (CT.EQ.1.AND.ST(6,K).LE.45.0) GO TO 103
      IF (CT.EQ.1.AND.ST(6,K).GT.45.0) GO TO 104
      IF (CT.EQ.2.AND.ST(6,K).LE.45.0) GO TO 105
      IF (CT.EQ.2.AND.ST(6,K).GT.45.0) GO TO 106
  101 CCM=0.598+0.00026*TC(K)+0.0021*(TC(K)**2)-0.00035*(TC(K)**3)
      GO TO 107
  102 CCM=0.908-0.03214*TC(K)+0.0102*(TC(K)**2)-0.00114*(TC(K)**3)
      GO TO 107
  103 CCM=0.849-0.01277*TC(K)+0.0036*(TC(K)**2)-0.00059*(TC(K)**3)
      GO TO 107
  104 CCM=1.010-0.01394*TC(K)+0.00553*(TC(K)**2)-0.00068*(TC(K)**3)
      GO TO 107
  105 CCM=0.724-0.00652*TC(K)+0.00191*(TC(K)**2)-0.00047*(TC(K)**3)
      GO TO 107
  106 CCM=0.959-0.02304*TC(K)+0.00787*(TC(K)**2)-0.00091*(TC(K)**3)
  107 IF( COS(HA) - TAN(DEC/BLAT)) 11,11,12
   11 COSS = -1.0 * COSSS
      ST(5,K) = ARCOS(COSS) * 57.296
      ST(7,K)=180.0- (ARSIN(COSW/COS(SALT)))*57.296
      GO TO 99
   12 COSS = COSSS
      ST(5,K) = ARCOS(COSS) * 57.296
      ST(7,K)= (ARSIN(COSW/COS(SALT)))*57.296
```

B2. Continued

```
  99 ST(9.K)=(AA*CN*CCN) /EXP(B/COSZ)
     ST(10.K) = C*ST(9.K) /(CN**2)
     ST(11.K) = R*(ST(10.K) + ST(9.K)*COSZ)
     WT = WALLT(IJK) / 57.296
     WA = WALLA(IJK) / 57.296
     ALPHA = COS(WT)
     BETA = SIN(WA) * SIN(WT)
     GAMMA = COS(WA) * SIN(WT)
     COSINC = ALPHA*COSZ + BETA*COSW + GAMMA*COSS
     ST(15.K) = ARCOS(COSINC) * 57.296
     IF(COSINC.GT.-0.20) GO TO 212
     ST(12.K) = 0.45
     GO TO 265
 212 ST(12.K)= 0.55 + 0.437*COSINC + 0.313*COSINC**2
 265 IF (COSINC.GT.0.0) GO TO 111
 112 ST(16.K) = 0.0
     TO = 0.
     AOOUT= 0.0
     AOIN = 0.
     GO TO 163
 111 ST(16.K) = ST(9.K)*COSINC
     TO = 0.
     AOIN = 0.
     AOOUT = 0.
     DO 200 J=1.6.1
     S = FLOAT(J) - 1.0
     TO = T(J) * (COSINC**S) + TO
     AOOUT = AOUT(J) * (COSINC**S) + AOOUT
 200 AOIN = AIN(J)*(COSINC**S)    + AOIN
     ST(13.K) = TO
     ST(14.K) = AOIN
     ST(8.K) = AOOUT
 163 IF (WALLT(IJK).GT.0.0) GO TO 1692
     SKY=ST(9.K)*C
     GO TO 1693
1692 IF (WALLT(IJK).NE.90.0) GO TO 1694
     SKY=ST(9.K)*(C*ST(12.K)+(R/2.0)*(C+SIN(SALT)))
     GO TO 1693
1694 SKY=ST(10.K)*((1.0+ALPHA)/2.0)
1693 GRD=ST(11.K)*((1.0-ALPHA)/2.0)
     ST(19.K)=ST(16.K)+SKY+GRD
     ST(23.K)=DT(K)+(ARO*ST(19.K))-(2.*ALPHA*(10.0-TC(K))/HO)
     DDD=ST(16.K)*(TO+NII*AOIN+NIO*AOOUT)
     DD=(SKY+GRD)*(TC+NIO*ADOUT+NII*ADIN)
     ST(20.K)=DDD+DD
1100 CONTINUE
     IF (ICNT.EQ.0) GO TO 2099
     IF (ICNT.EQ.1) GO TO 2017
     IF (ICNT.EQ.2) GO TO 2018
     IF (ICNT.EQ.3) GO TO 2019
2099 JJ=1
     KK=24
     GO TO 2026
2017 JJ=25
     KK=48
     GO TO 2026
2018 JJ=49
     KK=72
     GO TO 2026
2019 JJ=73
```

B2. Continued

```
      KK=96
 2026 DO 2106 N=JJ,KK
      IF(ICNT.EQ.0) GO TO 4017
      IF(ICNT.EQ.1) GO TO 4018
      IF(ICNT.EQ.2) GO TO 4019
      K=N-72
      GO TO 4020
 4017 K=N
      GO TO 4020
 4018 K=N-24
      GO TO 4020
 4019 K=N-48
 4020 M=MM
      SA(M,N)=ST(1,K)
      M=MM+1
      SA(M,N)=ST(2,K)
      M=MM+2
      SA(M,N)=ST(6,K)
      M=MM+3
      SA(M,N)=ST(7,K)
      M=MM+4
      SA(M,N)=ST(9,K)
      M=MM+5
      SA(M,N)=ST(16,K)
      M=MM+6
      SA(M,N)=ST(19,K)
      M=MM+7
      SA(M,N)=ST(20,K)
      M=MM+8
      SA(M,N)=ST(23,K)
      M=MM+9
      SA(M,N)=ST(22,K)
      M=MM+10
      SA(M,N)=ST(24,K)
 2106 CONTINUE
      MM=M+10
 2100 CONTINUE
 6100 IF (ICNT.EQ.TNT) GO TO 9998
      ICNT=ICNT+1
      GO TO 9999
 9998 RETURN
      END
```

B3. Subroutine NAMEA1.

```
C          FORTRAN PROGRAM TO EVALUATE Z-TRANSFORMS FOR CALCULATION OF
C       TRANSIENT HEAT TRANSFERS THROUGH WALLS AND ROOFS.
C
C          THIS PROGRAM WILL DERIVE THE Z-TRANSFER FUNCTIONS FOR TWO
C       TYPES OF BOUNDARY CONDITIONS AND THE FORM OF BOUNDARY PARAMETERS
C       MUST BE SPECIFIED.
C
C       BOUNDARY CONDITIONS:
C          OF THE FIRST KIND; (TEMPERATURE GIVEN FOR BOTH SURFACES).
C       A) RAMP INPUT                   ICASE=1
C       B) FREQUENCY RESPONSE           ICASE=2
C
C          OF THE SECOND KIND; (FLUX GIVEN FOR BOTH SURFACES).
C       A) STEP INPUT                   ICASE=3
C       B) RAMP INPUT                   ICASE=4
C       C) FREQUENCY RESPONSE           ICASE=5
C
C          INPUT TO PROGRAM:
C       CARD(1)       DT (F10.3)        DT=SAMPLING TIME INTERVAL.
C       CARD(2)*
C             * DESCRIPTION OF THE SLAB FOR TITLE PURPOSE ONLY (80A1).
C       CARD(3)*
C
C       CARD(4)   *
C         "       *
C       CARD(I+3)* XL(I),XK(I),D(I),SH(I),RES(I),(TEXT(I,J),J=1,30) WHERE
C         "       * I INDICATES THE I'TH LAYER OF THE SLAB (5F10.4,30A1).
C         "       *
C       CARD(M+3)*
C          WHERE XL=THICKNESS OF LAYER.
C                XK=THERMAL CONDUCTIVITY.
C                 D=DENSITY.
C                SH=SPECIFIC HEAT.
C               RES=RESISTANCE OF RADIATION PATH WHENEVER APPLICABLE
C                   OR THERMAL RESISTANCE OF LAYER WHEN THERE IS
C                   NEGLIGIBLE HEAT STORAGE.
C              TEXT=DESCRIPTION OF LAYER. A SECOND CARD AND SO ON CAN BE
C                   USED BY INSERTING ANY INTEGER IN COLUMN ONE(1).
C                 M=NUMBER OF LAYERS THE SLAB IS COMPOSED OF.
C        CARD(M+4)     BLANK CARD TC STOP ABOVE INPUT.
C        CARD(M+5)     ICASE,NW (I1,I1)
C                      WHERE:  NW=NUMBER OF FREQUENCIES TO BE USED WHEN
C                            FREQUENCY RESPONSE IS INVOLVED.
C        CARD(M+6)      W(2),W(3)...............W(NW+1) (8F10.4)
C                       ABOVE CARD ONLY READ WHEN FREQUENCY RESPONSE IS
C                       INVOLVED. (ICASE=2 OR ICASE=5) W(1) IS SET TO 0.0
C                       W(I)'S ARE THE PERIODS.
C
C        NOMENCLATURE:
C            RR=THICKNESS/THERMAL CONDUCTIVITY (XL/XK)
C               OR THERMAL RESISTANCE OF LAYER WHEN THERE IS
C               NEGLIGIBLE HEAT STORAGE. THEN RES=0.0
C            BETA*BETA=XL*XL*D*SH/XK
C            CO=THERMAL CONDUCTANCE AND USED AS 1/C'AT THE POLE FOR ICASE=4
C            AFTER A RUN IS COMPLETED CONTROL RETURNS TO READING CARD(1)
C            THEREFORE A BLANK CARD IN THIS LOCATION TERMINATES THE PROGRAM
C
C
```

B3. Continued

```
      SUBROUTINE NAMEA1(EE1,EE2)
      EXTERNAL POLES,MATRIX,ORIGIN,POLYM,AIRCAV,SOLVD,FREQRE
      DOUBLE PRECISION RR(20),BETA(20),XL(20),XK(20),D(20),SH(20),
     9RES(20),ROOT(900),FUNC(900,4),DER(900,4),DN(900,3),MP(2,2),
     8MPP(2,2),POL1(900),POL2(900),POL3(900),POL4(900),POL5(900),
     7POL6(900),MX(11,11),X(11),Y(11),Z(11),TEM1(2),TEM2(2),TEM3(2),
     6DT,C0,C1X,C1Y,C1Z,C2X,C2Y,C2Z,T,ARG1,ARG2,PREC,DET,TEST,W(6),
     1A1(120),A2(120),A3(120),AZ(120),B1(120),B2(120),B3(120),BZ(120),
     2C1(120),C2(120),C3(120),CZ(120),D1(120),D2(120),D3(120),DZ(120),
     3SA(250,100),AVH
      COMMON A1,A2,A3,AZ,B1,B2,B3,BZ,C1,C2,C3,CZ,D1,D2,D3,DZ,
     1KXX,KXY,KXZ,KYX,AVH,SA
      COMPLEX*16 A(6,2,2),TEMP,TEMP1,TEMP2,TEMP3
      INTEGER CARD,PRINT,TEXT(20,30),TEXT1(2,80)
      EQUIVALENCE (TEMP1,TEM1(1)),(TEMP2,TEM2(1)),(TEMP3,TEM3(1))
      CARD=5
      PRINT=6
      PREC=0.0
      W(1)=0.0
 1000 READ(CARD,1) DT,ICOMP,ZZZ
    1 FORMAT(   F10.3,I2,F2.0)
      IF(DT.EQ.0.0) GO TO 2000
      READ(CARD,2) ((TEXT1(I,J),J=1,80),I=1,2)
    2 FORMAT(   80A1)
      WRITE(PRINT,3) ((TEXT1(I,J),J=1,80),I=1,2)
    3 FORMAT('1',///////////////27X,80A1/27X,80A1)
      WRITE(PRINT,4)
    4 FORMAT(1H0,'LAYER',1X,'THICKNESS',4X,'CONDUCTIVITY',8X,'DENSITY',
     18X,'SP HEAT',11X,'RESISTANCE')
      WRITE(PRINT,5)
    5 FORMAT(2X,'   ',5X,'  ',4X,'                 ',3X,'           '
     1,2X,'             ',2X,'                    ',4X,'DESCRIPTION
     2OF LAYER'/)
      C0=0.0
      I=0
      DO 10 N=1,40
      I=I+1
      N=I
      READ(CARD,6) XL(I),XK(I),D(I),SH(I),RES(I),(TEXT(I,J),J=1,30)
    6 FORMAT(   5F10.4,30A1)
      IF(XL(I).NE.100) GO TO 2025
      CALL AIRCAV(RESI,EE1,EE2,ZZZ)
      RES(I)=RESI
      XL(I)=0.0
 2025 IF(RES(I).EQ.0.0.AND.SH(I).EQ.0.0.AND.XL(I).NE.0.0) GO TO 20
      IF(RES(I).EQ.0.0.AND.XL(I).EQ.0.0) GO TO 30
      IF(XL(I).NE.0.0) GO TO 40
      RR(I)=RES(I)
      BETA(I)=0.0
      GO TO 50
   40 RR(I)=XL(I)/XK(I)
      BETA(I)=XL(I)*DSQRT(D(I)*SH(I)/XK(I))
      C0=C0+RES(I)
   50 C0=C0+RR(I)
      WRITE(PRINT,7) I,XL(I),XK(I),D(I),SH(I),RES(I),(TEXT(I,J),J=1,30)
    7 FORMAT(1X,I3,F10.4,F15.4,F18.4,F15.4,F20.4,13X,30A1)
      GO TO 10
   20 WRITE(PRINT,8) (TEXT(I,J),J=1,30)
    8 FORMAT(95X,30A1)
      I=I-1
```

B3. Continued

```
   10 CONTINUE
      M=21
   30 M=M-1
      DO 60 I=1.M
      IF(XL(I).NE.0.0) GO TO 60
      RES(I)=0.0
   60 CONTINUE
      C0=1.0/C0
      WRITE(PRINT.1)
      WRITE(PRINT.1)
      THER=C0
      WRITE(PRINT.9) C0
    9 FORMAT(30X.'THERMAL CONDUCTANCE.   U='.F6.3.2X.'BTUS/HR FT FT
     1 DEGF          ')
      WRITE(PRINT.1)
      WRITE(PRINT.11) DT
   11 FORMAT(39X.'SAMPLING TIME INTERVAL.  DT='.F9.3.'HR.')
      WRITE(PRINT.1)
      READ(CARD.12) ICASE.NW
   12 FORMAT(    I1.I1)
      NW=NW+1
      MW=NW*2-1
      IF(ICASE.NE.2.AND.ICASE.NE.5) GO TO 65
      READ(CARD.13) (W(I).I=2.NW)
   13 FORMAT(    8F10.4)
      DO 61 I=2.NW
   61 W(I)=2.0*3.14159265/W(I)
   65 IF(ICASE.LT.3) GO TO 70
      IX=2
      JX=1
      GO TO 80
   70 IX=1
      JX=2
   80 CALL POLES(RR.BETA.RES.ROOT.DER.FUNC.M.IX.JX.DT.IROOT.ICASE)
      DO 90 I=1.900
      POL1(I)=0.0
      POL2(I)=0.0
      POL3(I)=0.0
      POL4(I)=0.0
      POL5(I)=0.0
   90 POL6(I)=0.0
      MMM=1
      NNN=0
      POL1(1)=1.0
      DO 100 I=1.IROOT
      POL2(1)=1.0
      POL2(2)=-DEXP(-ROOT(I)*DT)
      IF(DABS(POL2(2)).LT.1.0D-16)GO TO 110
      CALL POLYM(POL1.POL2.NNN.MMM)
  100 CONTINUE
  110 IF(ICASE.LT.3) GO TO 120
      POL2(1)=1.0
      POL2(2)=-1.0
      CALL POLYM(POL1.POL2.NNN.MMM)
  120 ID=NNN+1
      IF(ICASE.EQ.2.OR.ICASE.EQ.5) GO TO 130
      CALL ORIGIN(RR.BETA.RES.M.MP.MPP)
      GO TO(140.140.150.150.150).ICASE
  140 C1Y=-C0*C0*MP(1.2)
      C1X=C1Y+MP(2.2)*C0
```

B3. Continued

```
      C1Z=C1Y+MP(1,1)*C0
      GO TO 160
  150 C0=1.0/MP(2,1)
      C1Y=-C0*C0*MPP(2,1)/2.0
      C1X=MP(2,2)*C0+C1Y
      C1Z=MP(1,1)*C0+C1Y
  160 C2X=0.0
      C2Y=0.0
      C2Z=0.0
      DO 170 I=1,IROOT
      IF(ICASE.GT.1) GO TO 180
      DN(I,2)=1.0/ROOT(I)/ROOT(I)/DER(I,2)
      GO TO 200
  180 IF(ICASE.EQ.4) GO TO 190
      DN(I,2)=-1.0/ROOT(I)/DER(I,3)
      GO TO 200
  190 DN(I,2)=1.0/ROOT(I)/ROOT(I)/DER(I,3)
  200 DN(I,1)=DN(I,2)*FUNC(I,4)
      DN(I,3)=DN(I,2)*FUNC(I,1)
      IF(ICASE.NE.4) GO TO 170
      C2X=C2X-DN(I,1)
      C2Y=C2Y-DN(I,2)
      C2Z=C2Z-DN(I,3)
  170 CONTINUE
      DO 210 I=1,ID
  210 POL2(I)=POL1(I)
      IF(ICASE.EQ.3) GO TO 220
      POL3(1)=1.0/DT
      POL3(2)=-2.0/DT
      POL3(3)=1.0/DT
      MMM=2
      GO TO 235
  220 POL3(1)=1.0
      POL3(2)=-1.0
      MMM=1
  235 CALL POLYM(POL2,POL3,NNN,MMM)
      POL3(1)=0.0
      POL3(2)=0.0
      POL3(3)=0.0
      DO 230 I=1,900
      II=I
      T=I*DT
      DO 240 J=1,IROOT
      IF(ROOT(J)*T.GE.40.0) GO TO 250
      POL3(I)=POL3(I)+DEXP(-ROOT(J)*T)*DN(J,1)
      POL4(I)=POL4(I)+DEXP(-ROOT(J)*T)*DN(J,2)
      POL5(I)=POL5(I)+DEXP(-ROOT(J)*T)*DN(J,3)
      IF(J.LE.10) GO TO 240
      IF(DABS(DEXP(-ROOT(J)*T)*DN(J,2)).LT.1.0D-16) GO TO 250
  240 CONTINUE
  250 IF(ICASE.EQ.4) GO TO 260
      POL3(I)=POL3(I)+C0*T+C1X
      POL4(I)=POL4(I)+C0*T+C1Y
      POL5(I)=POL5(I)+C0*T+C1Z
      GO TO 270
  260 POL3(I)=POL3(I)+C0*T*T /2.0+C1X*T+C2X
      POL4(I)=POL4(I)+C0*T*T /2.0+C1Y*T+C2Y
      POL5(I)=POL5(I)+C0*T*T /2.0+C1Z*T+C2Z
  270 IF(I.LE.10) GO TO 230
      IF(DABS(POL4(I)).LT.1.0D-16) GO TO 280
```

B3. Continued

```
  230 CONTINUE
  280 MMM=II-1
      IF(ICASE.LT.3) GO TO 281
      DO 282 I=1,899
      II=901-I
      POL3(II)=POL3(II-1)
      POL4(II)=POL4(II-1)
  282 POL5(II)=POL5(II-1)
      POL3(1)=0.0
      IF(XL(M).EQ.0.0) POL3(1)=RR(M)
      POL4(1)=0.0
      POL5(1)=0.0
      IF(XL(1).EQ.0.0) POL5(1)=RR(1)
      MMM=MMM+1
      IF(ICASE.EQ.4) POL3(1)=0.0
      IF(ICASE.EQ.4) POL5(1)=0.0
  281 NN=NNN+1
      DO 290 I=1,NN
  290 POL6(I)=POL2(I)
      CALL POLYM(POL6,POL3,NNN,MMM)
      NN1=NNN+1
      DO 300 I=1,NN1
  300 POL3(I)=POL6(I)
      DO 310 I=1,NN
  310 POL6(I)=POL2(I)
      NNN=NN-1
      CALL POLYM(POL6,POL4,NNN,MMM)
      NN2=NNN+1
      DO 320 I=1,NN2
  320 POL4(I)=POL6(I)
      DO 330 I=1,NN
  330 POL6(I)=POL2(I)
      NNN=NN-1
      CALL POLYM(POL6,POL5,NNN,MMM)
      NN3=NNN+1
      DO 340 I=1,NN3
  340 POL5(I)=POL6(I)
      GO TO 350
  130 DO 360 I=1,MW,2
      DO 360 J=1,MW
      IF(I.EQ.1) GO TO 370
      K=(I+1)/2
      MX(I,J)=DSIN((J-1)*DT*W(K))
      GO TO 360
  370 MX(I,J)=1.0
  360 CONTINUE
      LW=MW-1
      DO 380 I=2,LW,2
      DO 380 J=1,MW
      K=I/2+1
  380 MX(I,J)=DCOS((J-1)*DT*W(K))
  381 CALL SOLVD(MX,11,MW,MW,PREC,DET,TEST)
      CALL FREQRE (RR,BETA,RES,XL,XK,D,SH,M,W,A,NW)
      DO 390 I=1,MW,2
      IF(I.EQ.1) GO TO 390
      K=(I+1)/2
      ARG1=0.0
      ARG2=0.0
      DO 410 J=1,ID
      ARG1=ARG1+POL1(J)*DCOS((J-1)*DT*W(K))
```

B3. Continued

```
  410 ARG2=ARG2-POL1(J)*DSIN((J-1)*DT*W(K))
      TEMP=DCMPLX(ARG1,ARG2)
      IF(ICASE.EQ.2) GO TO 420
      TEMP1=TEMP*A(K,2,2)/A(K,2,1)
      TEMP2=TEMP/A(K,2,1)
      TEMP3=TEMP*A(K,1,1)/A(K,2,1)
      GO TO 430
  420 TEMP1=TEMP*A(K,2,2)/A(K,1,2)
      TEMP2=TEMP/A(K,1,2)
      TEMP3=TEMP*A(K,1,1)/A(K,1,2)
  430 X(I-1)=TEM1(1)
      X(I)=-TEM1(2)
      Y(I-1)=TEM2(1)
      Y(I)=-TEM2(2)
      Z(I-1)=TEM3(1)
      Z(I)=-TEM3(2)
  390 CONTINUE
      IF(ICASE.EQ.2) GO TO 391
      X(1)=0.0
      DO 392 I=1,M
  392 X(1)=X(1)+SH(I)*D(I)*XL(I)
      X(1)=-DT/X(1)
      Y(1)=0.0
      DO 394 I=1,ID
  394 Y(1)=Y(1)+I*POL1(I+1)
      X(1)=X(1)*Y(1)
      Y(1)=X(1)
      Z(1)=X(1)
      GO TO 393
  391 ARG1=0.0
      DO 440 J=1,ID
  440 ARG1=ARG1+POL1(J)
      TEMP=DCMPLX(ARG1,0.0D+01)
      IF(ICASE.EQ.2) GO TO 450
      TEMP1=TEMP*A(1,2,2)/A(1,2,1)
      TEMP2=TEMP/A(1,2,1)
      TEMP3=TEMP*A(1,1,1)/A(1,2,1)
      GO TO 460
  450 TEMP1=TEMP*A(1,2,2)/A(1,1,2)
      TEMP2=TEMP/A(1,1,2)
      TEMP3=TEMP*A(1,1,1)/A(1,1,2)
  460 X(1)=TEM1(1)
      Y(1)=TEM2(1)
      Z(1)=TEM3(1)
  393 DO 470 I=1,MW
      POL3(I)=0.0
      POL4(I)=0.0
  470 POL5(I)=0.0
      DO 480 I=1,MW
      DO 480 J=1,MW
      POL3(I)=POL3(I)+MX(I,J)*X(J)
      POL4(I)=POL4(I)+MX(I,J)*Y(J)
  480 POL5(I)=POL5(I)+MX(I,J)*Z(J)
      NN1=MW
      NN2=MW
      NN3=MW
      IF(ICASE.NE.5) GO TO 350
      NN1=NN1+1
      NN2=NN2+1
      NN3=NN3+1
```

B3. Continued

```
      DO 481 I=1,14
      J=16-I
      POL3(J)=PCL3(J-1)
      POL4(J)=POL4(J-1)
  481 POL5(J)=PCL5(J-1)
      POL3(1)=0.0
      POL4(1)=0.0
      POL5(1)=0.0
  350 IF(ICASE.EQ.3) GO TO 490
      IF(ICASE.EQ.2.OR.ICASE.EQ.5) GO TO 500
      WRITE(PRINT,14)
   14 FORMAT(44X,'COEFFICIENTS FOR RAMP INPUT')
      GO TO 510
  490 WRITE(PRINT,15)
   15 FORMAT(44X,'COEFFICIENTS FOR STEP INPUT')
      GO TO 510
  500 WRITE(PRINT,16)
   16 FORMAT(44X,'COEFFICIENTS BY FREQUENCY RESPONSE')
      DO 501 I=2,NW
  501 W(I)=2.0*3.14159265/W(I)
      WRITE(PRINT,22) (W(I),I=2,NW)
   22 FORMAT('0',20X,'PERIODS',8F10.1)
  510 WRITE(PRINT,1)
      IF(ICASE.GT.2) GO TO 520
      WRITE(PRINT,17)
   17 FORMAT(14X,'J',18X,'D/B',19X,'1/B',19X,'A/B',17X,'D(Z)')
      GO TO 530
  520 WRITE(PRINT,18)
   18 FORMAT(14X,'J',18X,'D/C',19X,'1/C',19X,'A/C',17X,'D(Z)')
  530 NN=MIN0(NN1,NN2,NN3)
      N=MAX0(NN,ID)
      DO 540 I=1,N
      J=I-1
      IF(I.LE.ID.AND.I.LE.NN) GO TO 550
      IF(NN.LT.ID) GO TO 570
      GO TO 560
  570 WRITE(PRINT,19) J,POL1(I)
   19 FORMAT(9X,I6,68X,F20.6)
      GO TO 540
  560 WRITE(PRINT,21) J,PCL3(I),POL4(I),POL5(I)
   21 FORMAT(9X,I6,F24.6,F22.6,F22.6,F20.6)
      GO TO 540
  550 WRITE(PRINT,21) J,POL3(I),POL4(I),POL5(I),POL1(I)
  540 CONTINUE
C     COEFFICIENTS
C     WALL  A1,A2,A3,AZ
C     PITCHED ROOF B1,B2,B3,BZ
C     HORIZONTAL ROOF  C1,C2,C3,CZ
C     DOORS  D1,D2,D3,DZ
      GO TO (301,302,303,304),ICOMP
  301 DO 24 I=1,N
      A1(I)=POL3(I)
      A2(I)=POL4(I)
      A3(I)=POL5(I)
      AZ(I)=POL1(I)
   24 CONTINUE
      KXX=N
      GO TO 1000
  302 DO 28 I=1,N
      B1(I)=POL3(I)
```

B3. Continued

```
      B2(I)=POL4(I)
      B3(I)=POL5(I)
      BZ(I)=POL1(I)
   28 CONTINUE
      KXY=N
      GO TO 1000
  303 DO 26 I=1,N
      C1(I)=POL3(I)
      C2(I)=POL4(I)
      C3(I)=POL5(I)
      CZ(I)=POL1(I)
   26 CONTINUE
      KXZ=N
      GO TO 1000
  304 DO 27 I=1,N
      D1(I)=POL3(I)
      D2(I)=POL4(I)
      D3(I)=POL5(I)
      DZ(I)=POL1(I)
   27 CONTINUE
      KYX=N
      GO TO 1000
 2000 WRITE(PRINT,3)
      RETURN
      END
```

B4. Subroutine POLES.

```
C      SUBROUTINE POLES(RR.BETA.RES.ROOT.DER.FUNC.M.II.IJ.DT.IROOT.ICASE)
C
C           SUBROUTINE TO CALCULATE THE ROOTS OF THE HEAT TRANSFER MATRIX
C      AND WILL STORE THE VALUE OF THE FUNCTIONS AND THE FIRST DERIVATIVE
C      AT THE ROOTS.
C
C           THE MAXIMUM NUMBER OF ROOTS THAT CAN BE OBTAINED IS SET
C      AT ONE HUNDRED(900)
C
C           THIS METHOD WILL FIRST FIND A ROOT BETWEEN 30.0/DT AND
C      100.0/DT. BEING ASSUMED THAT A ROOT EXIST IN THIS INTERVAL. THIS
C      ROOT IS ALSO LARGE ENOUGH TO GIVE SUFFICIENT ACCURACY TO EVALUATE
C      THE RESPONSE FACTORS.
C           THE METHOD CHECKS THE INTERVAL BETWEEN THE ORIGIN AND THIS
C      FIRST ROOT AND WHEN ANOTHER ROOT IS FOUND THE INTERVAL NEXT TO BE
C      CHECKED BECOMES THE INTERVAL BETWEEN THIS NEW ROOT AND THE NEXT
C      LARGEST ROOT AND SO ON. WHEN NO ROOT EXIST IN AN INTERVAL THE NEXT
C      SMALLEST INTERVAL IS SELECTED AND SO ON WORKING TOWARDS THE ORIGIN
C      UNTIL ALL ROOTS ARE FOUND.
C           TO CHECK FOR A ROOT THE METHOD SUBDIVIDES THE INTERVALS IN
C      RELATIVELY LARGE SEGMENTS AND CHECKS FOR BOTH A CHANGE IN SIGN OF
C      THE FUNCTION AND FOR TWO CHANGES IN DIRECTION OF THE SLOPE OF THE
C      FUNCTION. IF A ROOT EXIST. BY MAKING THESE TWO CHECKS. IT IS
C      INDICATED SO IN A RELATIVELY SHORT TIME. ONCE IT IS INDICATED THAT
C      A ROOT DOES EXIST IN A CERTAIN SEGMENT OF AN INTERVAL. THIS
C      SEGMENT IS FURTHER SUBDIVIDED AND USING A SIMILAR ROUTINE AS ABOVE
C      EXCEPT CHECKING FOR A CHANGE IN SIGN OF THE FUNCTION ONLY. IF ON
C      THE FIRST PASS A CHANGE IN SIGN IS NOT FOUND THE SEGMENT IS FURTHE
C      SUBDIVIDED INTO EVEN SMALLER PARTS UNTIL A CHANGE IN SIGN DOES
C      OCCUR. ONCE A CHANGE IN SIGN OCCURS THE ROOT IS ARRIVED AT BY
C      SPLITTING THIS INTERVAL SUCCESSIVELY IN HALF USING THE NEW SEGMENT
C      WITH FUNCTION VALUE OF OPPOSITE SIGN UNTIL A ROOT IS REACHED
C      WITHIN AN ACCURACY OF 10-14.
C           THE SPLITTING OF THE SEGMENTS TO ARRIVE AT A ROOT IS USED
C      BECAUSE A RELATIVELY CONSTANT NUMBER OF ITERATIONS ARE REQUIRED
C      TO OBTAIN THE ACCURACY WANTED. IN THE CASE OF THE REGULA FALSI
C      METHOD IT WAS FOUND THAT THE NUMBER OF ITERATIONS VARIED FROM AS
C      LOW AS FIVE (5) TO MORE THAN THREE HUNDRED (300) ITERATIONS. IN TH
C      LONG RUN IT WAS FOUND THAT THE SPLITTING OF THE POINTS REQUIRED
C      LESS RUNNING TIME.
C
C      NOMENCLATURE:
C           RR=THICKNESS/THERMAL CONDUCTIVITY (XL/XK)
C              OR THERMAL RESISTANCE OF LAYER WHEN THERE IS
C              NEGLIGIBLE HEAT STORAGE
C           BETA*BETA=XL*XL*D*SH/XK
C                   WHERE      D=DENSITY.
C                              SH=SPECIFIC HEAT.
C           RES=RESISTANCE OF RADIATION PATH WHENEVER APPLICABLE.
C
C           ROOT=CONTAINS THE ROOTS OF THE HEAT TRANSFER FUNCTIONS
C                ON RETURN.
C           DER=CONTAINS THE DERIVATIVE OF THE HEAT TRANSFER FUNCTIONS
C               AT THE ROOTS ON RETURN.
C           FUNC=CONTAINS THE VALUE OF THE HEAT TRANSFER FUNCTIONS
C                AT THE ROOTS ON RETURN.
C
C           M=NUMBER OF LAYERS THE SLAB IS COMPOSED OF.
```

B4. Continued

```
C
C        II AND IJ ARE THE ROW AND COLUMN SUBSCRIPTS OF THE ELEMENT OF
C        THE MATRIX FOR WHICH THE ROOT IS FOUND.
C        II=1*
C            * BOUNDARY CONDITION OF THE FIRST KIND.
C        IJ=2*
C
C        II=2*
C            * BOUNDARY CONDITION OF THE SECOND KIND.
C        IJ=1*
C
C        DT=TIME INTERVAL OF SAMPLING
C
      SUBROUTINE POLES(RR,BETA,RES,ROOT,DER,FUNC,M,II,IJ,DT,IROOT,ICASE)
      DOUBLE PRECISION RR(20),BETA(20),RES(20),ROOT(900),DER(900,4),
     1FUNC(900,4),F(2,2),FF(2,2),R1,R2,R3,F1,F2,F3,FP1,FP2,FP3,RTEMP,
     2FTEMP,DT
      DO 10 I=1,900
      DO 20 J=1,4
      FUNC(I,J)=0.0
   20 DER(I,J)=0.0
   10 ROOT(I)=0.0
      LAST=0
      R1=30.0/DT
      R3=100.0/DT
      IF(ICASE.EQ.4) R1=450.0/DT
      IF(ICASE.EQ.4) R3=700.0/DT
      IROOT=0
      DO 30 IIROOT=1,1800
      IROOT=IROOT+1
      IF(IROOT.EQ.1) GO TO 40
C     FOLLOWING IS THE ROUTINE CHECKING FOR A CHANGE IN THE SIGN OF THE
C     FUNCTION AND ALSO FOR TWO(2) CHANGES IN DIRECTION OF THE SLOPE. TO
C     FIND WHETHER A ROOT EXIST OR NOT.
  300 CALL MATRIX(RR,BETA,RES,R1,M,F,FF,2)
      F1=F(II,IJ)
      FP1=FF(II,IJ)
      IC=0
      DO 50 I=1,20
      R2=R1+(R3-R1)/20.0*I
      CALL MATRIX(RR,BETA,RES,R2,M,F,FF,2)
      F2=F(II,IJ)
      FP2=FF(II,IJ)
      IF(F1.GT.0.0) GO TO 60
      IF(F2.LE.0.0) GO TO 70
      GO TO 80
   60 IF(F2.LE.0.0) GO TO 80
   70 IF(FP1.GT.0.0) GO TO 90
      IF(FP2.GT.0.0) GO TO 100
      GO TO 110
   90 IF(FP2.GT.0.0) GO TO 110
  100 IC=IC+1
      IF(IC.EQ.2) GO TO 80
  110 F1=F2
      FP1=FP2
   50 CONTINUE
      IROOT=IROOT-1
      LAST=LAST-1
  120 IF(LAST.EQ.0) GO TO 130
      IF(LAST.NE.1) GO TO 125
```

B4. Continued

```
      R1=0.0001/DT
      GO TO 140
  125 R1=ROOT(LAST-1)
  140 R3=ROOT(LAST)
      R1=R1+0.00001/DT
      R3=R3-0.00001/DT
      GO TO 30
   80 R3=R2
   40 N=1
      CALL MATRIX(RR.BETA.RES.R1.M.F.FF.1)
      F1=F(II.IJ)
      DO 150 I=N.25
      NN=10*I
      DO 160 J=1.NN
      R2=R1+J*(R3-R1)/NN
      CALL MATRIX(RR.BETA.RES.R2.M.F.FF.1)
      F2= F(II.IJ)
      IF(F1.GT.0.0) GO TO 170
      IF(F2.LE.0.0) GO TO 160
      GO TO 190
  170 IF(F2.LE.0.0) GO TO 190
      GO TO 160
  190 RTEMP=(R1+R2)/2.0
      CALL MATRIX(RR.BETA.RES.RTEMP.M.F.FF.1)
      FTEMP=F(II.IJ)
      IF(FTEMP.EQ.0.0) GO TO 200
      IF(FTEMP.GT.0.0) GO TO 210
      IF(F1.GT.0.0) GO TO 220
      F1=FTEMP
      R1=RTEMP
      GO TO 230
  220 F2=FTEMP
      R2=RTEMP
      GO TO 230
  210 IF(F1.GT.0.0) GO TO 215
      F2=FTEMP
      R2=RTEMP
      GO TO 230
  215 F1=FTEMP
      R1=RTEMP
  230 IF( DABS((R1-R2)/R1)-1.0D-14 .GT.0.0) GO TO 190
  200 CALL MATRIX(RR.BETA.RES.R2.M.F.FF.2)
      GO TO 240
  160 CONTINUE
  150 CONTINUE
      WRITE(3.1)
    1 FORMAT('0UNABLE TO FIND A ROOT AFTER INDICATION THAT A ROOT EXISTE
     1D')
      CALL EXIT
  240 DO 250 I=1.IROOT
      J=I+1
      IF(R2.GT.ROOT(I)) GO TO 250
      J=I+1
      GO TO 260
  250 CONTINUE
  260 LAST=LAST+1
      IF(IROOT.EQ.1) GO TO 270
      JJ=IROOT+1
      DO 280 I=J,IROOT
      JJ=JJ-1
```

B4. Continued

```
      ROOT(JJ)=ROOT(JJ-1)
      DO 280 K=1,4
      DER(JJ,K)=DER(JJ-1,K)
  280 FUNC(JJ,K)=FUNC(JJ-1,K)
  270 J=J-1
      ROOT(J)=R2
      DO 290 K=1,4
      KX=(K+1)/2
      KY=K/KX
      DER(J,K)=FF(KX,KY)
  290 FUNC(J,K)=F(KX,KY)
      GO TO 120
   30 CONTINUE
  130 RETURN
      END
```

B5. Subroutine MATRIX.

```
      SUBROUTINE MATRIX(RR,BETA,RES,W,M,F,FF,ICONT)
C
C         SUBROUTINE TO CALCULATE THE HEAT TRANSFER MATRIX FOR A SLAB,
C     AND THE DERIVATIVE OF THIS MATRIX.
C
C     IF ICONT=1 THE ROUTINE CALCULATES HEAT TRANSFER MATRIX ONLY.
C     IF ICONT=2 THE ROUTINE CALCULATES HEAT TRANSFER MATRIX AND ITS
C                DERIVATIVE.
C
C     NOMENCLATURE:
C         RR=THICKNESS/THERMAL CONDUCTIVITY (XL/XK)
C            OR THERMAL RESISTANCE OF LAYER WHEN THERE IS
C            NEGLIGIBLE HEAT STORAGE.
C         BETA*BETA=XL*XL*D*SH/K.
C                   WHERE D=DENSITY.
C                         SH=SPECIFIC HEAT.
C         RES=RESISTANCE OF RADIATION PATH WHENEVER APPLICABLE.
C
C         W=VALUES ALONG THE AXIS FOR WHICH THE MATRIX OR THE MATRIX
C           AND DERIVATIVES ARE FOUND.
C         M=NUMBER OF LAYERS THE SLAB IS COMPOSED OF.
C         F=CONTAINS THE VALUE OF THE HEAT TRANSFER MATRIX ON RETURN
C         FF=CONTAINS THE VALUE OF THE DERIVATIVE ON RETURN.
C
      DOUBLE PRECISION RR(20),BETA(20),F1(20,2,2),F2(20,2,2),F3(20,2,2),
     1F(2,2),FF(2,2),RES(20),P,R,ALPHA,SQ,W,TEMP,TEMP1
      DO 10 I=1,M
      P=DSQRT(W)*BETA(I)
      R=RR(I)
      ALPHA=BETA(I)
      SQ=DSQRT(W)
      IF(P.NE.0.0) GO TO 20
C     ELEMENTS OF THE MATRIX FOR LAYER I WHERE THERE IS NEGLIGIBLE
C     HEAT STORAGE.
      F1(I,1,1)=1.0
      F1(I,1,2)=R
      F1(I,2,1)=0.0
      F1(I,2,2)=1.0
      IF(ICONT.EQ.1) GO TO 10
C     DERIVATIVES OF THE ELEMENTS OF THE MATRIX FOR LAYER I WHERE THERE
C     IS NEGLIGIBLE HEAT STORAGE.
      F2(I,1,1)=0.0
      F2(I,1,2)=0.0
      F2(I,2,1)=0.0
      F2(I,2,2)=0.0
      GO TO 10
C     ELEMENTS OF THE MATRIX FOR LAYER I FOR HEAT TRANSFER BY CONDUCTION
C     ONLY.
   20 F1(I,1,1)=DCOS(P)
      F1(I,1,2)=R/P*DSIN(P)
      F1(I,2,1)=-P/R*DSIN(P)
      F1(I,2,2)=F1(I,1,1)
      IF(ICONT.EQ.1) GO TO 30
C     DERIVATIVES OF THE ELEMENTS OF THE MATRIX FOR LAYER I FOR HEAT
C     TRANSFER BY CONDUCTION ONLY.
      F2(I,1,1)=ALPHA*DSIN(ALPHA*SQ)/2.0/SQ
      F2(I,1,2)=-R*DCOS(ALPHA*SQ)/2.0/W+R*DSIN(ALPHA*SQ)/ALPHA/2.0/SQ/SQ
     1/SQ
```

B5. Continued

```
      F2(I,2,1)=ALPHA*ALPHA*DCOS(ALPHA*SQ)/2.0/R+DSIN(ALPHA*SQ)/2.0/SQ*
     1ALPHA/R
      F2(I,2,2)=F2(I,1,1)
   30 IF(RES(I).EQ.0.0) GO TO 10
C     ELEMENTS OF THE MATRIX FOR LAYER I WHERE THERE IS HEAT TRANSFER BY
C     CONDUCTION AND THERMAL RADIATION USING CONDUCTION PART FROM ABOVE.
      TEMP=1.0/(F1(I,1,2)+RES(I))
      F1(I,2,1)=(F1(I,2,1)*RES(I)+2.0*F1(I,1,1)-2.0)*TEMP
      F1(I,1,1)=(F1(I,1,1)*RES(I)+F1(I,1,2))*TEMP
      F1(I,2,2)=F1(I,1,1)
      F1(I,1,2)=F1(I,1,2)*RES(I)*TEMP
      IF(ICONT.EQ.1) GO TO 10
C     DERIVATIVES OF THE ELEMENTS OF THE MATRIX FOR LAYER I WHERE THERE
C     IS HEAT TRANSFER BY CONDUCTION AND THERMAL RADIATION USING
C     CONDUCTION PART FROM ABOVE
      TEMP1=F2(I,1,2)*TEMP
      F2(I,2,1)=(F2(I,2,1)*RES(I)+2.0*F2(I,1,1))*TEMP-F1(I,2,1)*TEMP1
      F2(I,1,1)=(F2(I,1,1)*RES(I)+F2(I,1,2))*TEMP-F1(I,1,1)*TEMP1
      F2(I,2,2)=F2(I,1,1)
      F2(I,1,2)=F2(I,1,2)*RES(I)*TEMP-F1(I,1,2)*TEMP1
   10 CONTINUE
C     RETURN IF ONLY ONE LAYER INVOLVED.
      IF((M-1).NE.0) GO TO 50
      DO 40 K=1,2
      DO 40 L=1,2
      IF(ICONT.EQ.1) GO TO 40
      FF(K,L)=F2(1,K,L)
   40 F(K,L)=F1(1,K,L)
      RETURN
   50 DO 60 K=1,2
      DO 60 L=1,2
   60 FF(K,L)=0.0
      IF(ICONT.EQ.1) GO TO 150
C     FOLLOWING IS THE ROUTINE TO COMBINE INDIVIDUAL DERIVATIVES OF THE
C     HEAT TRANSFER MATRICES TO GET THE OVERALL DERIVATIVE.
      DO 140 I=1,M
      DO 120 J=1,M
      DO 80 K=1,2
      DO 80 L=1,2
      IF((I-J).EQ.0) GO TO 70
      F3(J,K,L)=F1(J,K,L)
      GO TO 80
   70 F3(J,K,L)=F2(J,K,L)
   80 CONTINUE
      IF((J-1).EQ.0) GO TO 120
      DO 90 K=1,2
      DO 90 L=1,2
   90 F(K,L)=0.0
      DO 100 K=1,2
      DO 100 L=1,2
      DO 100 N=1,2
  100 F(K,L)=F(K,L)+F3(J-1,K,N)*F3(J,N,L)
      DO 110 L=1,2
      DO 110 K=1,2
  110 F3(J,K,L)=F(K,L)
  120 CONTINUE
      DO 130 K=1,2
      DO 130 L=1,2
  130 FF(K,L)=FF(K,L)+F(K,L)
  140 CONTINUE
```

B5. Continued

```
C     FOLLOWING IS THE ROUTINE TO COMBINE INDIVIDUAL HEAT TRANSFER
C     MATRIX TO GET THE OVERALL HEAT TRANSFER MATRIX.
  150 DO 190 I=2,M
      DO 160 K=1,2
      DO 160 L=1,2
  160 F(K,L)=0.0
      DO 170 K=1,2
      DO 170 L=1,2
      DO 170 N=1,2
  170 F(K,L)=F(K,L)+F1(I-1,K,N)*F1(I,N,L)
      DO 180 K=1,2
      DO 180 L=1,2
  180 F1(I,K,L)=F(K,L)
  190 CONTINUE
      RETURN
      END
```

B6. Subroutine ORIGIN.

```
      SUBROUTINE ORIGIN(RR.BETA.RES.M.MP.MPP)
C
C     SUBROUTINE TO CALCULATE THE RESIDUES AT THE POLES OF THE
C     Z-TRANSFER FUNCTIONS. (FIRST AND SECOND DERIVATIVES)
C
C     NOMENCLATURE:
C         RR=THICKNESS/THERMAL CONDUCTIVITY (XL/XK).
C            OR THERMAL RESISTANCE OF LAYER WHEN THERE IS
C            NEGLIGIBLE HEAT STORAGE.
C         BETA*BETA=XL*XL*D*SH/XK.
C                  WHERE D=DENSITY.
C                        SH=SPECIFIC HEAT.
C         RES=RESISTANCE OF RADIATION PATH WHENEVER APPLICABLE.
C
C         M=NUMBER OF LAYER THE SLAB IS COMPOSED OF.
C
C         MP=CONTAINS THE VALUE OF THE FIRST DERIVATIVE AT THE
C            POLES ON RETURN.
C         MPP=CONTAINS THE VALUE OF THE SECOND DERIVATIVE AT THE POLES
C             ON RETURN
C
      DOUBLE PRECISION RR(20).BETA(20).RES(20).MP(2.2).MPP(2.2).
     1A(20.2.2).B(20.2.2).C(20.2.2).D(2.2).E(2.2).F(2.2).G(2.2).
     2TEMP(2.2).TEMP1(2.2).P.R
      DO 10 I=1.2
      DO 10 J=1.2
      MP(I.J)= 0.0
   10 MPP(I.J)=0.0
      DO 40 I=1.M
      P=BETA(I)*BETA(I)
      R=RR(I)
C     ELEMENTS OF THE MATRIX AT THE POLE FOR LAYER I. FOR CONDUCTION
C     OR NEGLIGIBLE HEAT TRANSFER.
      A(I.1.1)=1.0
      A(I.1.2)=R
      A(I.2.1)=0.0
      A(I.2.2)=1.0
      IF(RES(I).EQ.0.0) GO TO 20
C     ELEMENTS OF THE MATRIX AT THE POLE FOR LAYER I. WHERE THERE IS
C     HEAT TRANSFER BY CONDUCTION AND THERMAL RADIATION.
      A(I.1.2)=R*RES(I)/(R+RES(I))
C     FIRST DERIVATIVE OF THE ELEMENTS OF THE MATRIX AT THE POLE
C     FOR LAYER I. FOR CONDUCTION OR NEGLIGIBLE HEAT STORAGE.
   20 B(I.1.1)=P/2.0
      B(I.1.2)=R*P/6.0
      B(I.2.1)=P/R
      B(I.2.2)=P/2.0
      IF(RES(I).EQ.0.0) GO TO 30
C     FIRST DERIVATIVE OF THE ELEMENTS OF THE MATRIX AT THE POLE
C     FOR LAYER I. WHERE THERE IS HEAT TRANSFER BY CONDUCTION AND
C     THERMAL RADIATION.
      B(I.1.1)=RES(I)*P/2.0/(R+RES(I))
      B(I.1.2)=(1.0-R/(R+RES(I)))*RES(I)*R*P/6.0/(R+RES(I))
      B(I.2.1)=(RES(I)*P/R+P)/(R+RES(I))
      B(I.2.2)=B(I.1.1)
C     SECOND DERIVATIVE OF THE ELEMENTS OF THE MATRIX AT THE POLE FOR
C     LAYER I. FOR CONDUCTION OR NEGLIGIBLE HEAT STORAGE.
   30 C(I.1.1)=P*P/12.0
```

B6. Continued

```
      C(I,1,2)=P*P*R/60.0
      C(I,2,1)=P*P/3.0/R
      C(I,2,2)=C(I,1,1)
   40 CONTINUE
C     RETURN IF ONLY ONE LAYER INVOLVED.
      IF((M-1).NE.0) GO TO 60
      DO 50 I=1,2
      DO 50 J=1,2
      MP(I,J)=B(1,I,J)
   50 MPP(I,J)=C(1,I,J)
      RETURN
C     FOLLOWING IS THE ROUTINE TO CALCULATE THE FIRST AND SECOND
C     DERIVATIVE OF THE HEAT TRANSFER MATRIX AT THE POLES FOR A
C     MULTILAYER SLAB.
   60 DO 280 I=1,M
      DO 260 K=1,M
      IF(I.NE.K) GO TO 80
      IF(I.NE.1) GO TO 70
      D(1,1)=B(1,1,1)
      D(1,2)=B(1,1,2)
      D(2,1)=B(1,2,1)
      D(2,2)=B(1,2,2)
      GO TO 80
   70 D(1,1)=A(1,1,1)
      D(1,2)=A(1,1,2)
      D(2,1)=A(1,2,1)
      D(2,2)=A(1,2,2)
   80 IF(I.NE.1) GO TO 90
      IF(K.NE.1) GO TO 100
      E(1,1)=C(1,1,1)
      E(1,2)=C(1,1,2)
      E(2,1)=C(1,2,1)
      E(2,2)=C(1,2,2)
      GO TO 120
   90 IF(K.NE.1) GO TO 110
  100 E(1,1)=B(1,1,1)
      E(1,2)=B(1,1,2)
      E(2,1)=B(1,2,1)
      E(2,2)=B(1,2,2)
      GO TO 120
  110 E(1,1)=A(1,1,1)
      E(1,2)=A(1,1,2)
      E(2,1)=A(1,2,1)
      E(2,2)=A(1,2,2)
  120 DO 240 J=2,M
      IF(I.NE.K) GO TO 170
      IF(I.EQ.J) GO TO 130
      F(1,1)=A(J,1,1)
      F(1,2)=A(J,1,2)
      F(2,1)=A(J,2,1)
      F(2,2)=A(J,2,2)
      GO TO 140
  130 F(1,1)=B(J,1,1)
      F(1,2)=B(J,1,2)
      F(2,1)=B(J,2,1)
      F(2,2)=B(J,2,2)
  140 DO 150 L=1,2
      DO 150 LL=1,2
      TEMP(L,LL)=0.0
      DO 150 LLL=1,2
```

B6. Continued

```
150 TEMP(L,LL)=TEMP(L,LL)+D(L,LLL)*F(LLL,LL)
    DO 160 L=1,2
    DO 160 LL=1,2
160 D(L,LL)=TEMP(L,LL)
170 IF(I.EQ.J) GO TO 180
    IF(K.EQ.J) GO TO 190
    G(1,1)=A(J,1,1)
    G(1,2)=A(J,1,2)
    G(2,1)=A(J,2,1)
    G(2,2)=A(J,2,2)
    GO TO 210
180 IF(K.EQ.J) GO TO 200
190 G(1,1)=B(J,1,1)
    G(1,2)=B(J,1,2)
    G(2,1)=B(J,2,1)
    G(2,2)=B(J,2,2)
    GO TO 210
200 G(1,1)=C(J,1,1)
    G(1,2)=C(J,1,2)
    G(2,1)=C(J,2,1)
    G(2,2)=C(J,2,2)
210 DO 220 L=1,2
    DO 220 LL=1,2
    TEMP1(L,LL)=0.0
    DO 220 LLL=1,2
220 TEMP1(L,LL)=TEMP1(L,LL)+E(L,LLL)*G(LLL,LL)
    DO 230 L=1,2
    DO 230 LL=1,2
230 E(L,LL)=TEMP1(L,LL)
240 CONTINUE
    DO 250 L=1,2
    DO 250 LL=1,2
250 MPP(L,LL)=MPP(L,LL)+TEMP1(L,LL)
260 CONTINUE
    DO 270 L=1,2
    DO 270 LL=1,2
270 MP(L,LL)=MP(L,LL)+TEMP(L,LL)
280 CONTINUE
    RETURN
    END
```

B7. Subroutine FREQRE.

```
      SUBROUTINE FREQRE (RR.BETA.RES.XL.XK.D.SH.M.W.A.LW)
C
C         THIS SUBROUTINE CALCULATES THE FUNCTIONS OF THE HEAT
C     TRANSFER MATRIX WHEN S=IW  WHERE I=SQRT(-1.0)
C
C     NOMENCLATURE:
C         RR=THICKNESS/THERMAL CONDUCTIVITY (XL/XK)
C            OR THERMAL RESISTANCE OF LAYER WHEN THERE IS
C            NEGLIGIBLE HEAT STORAGE.
C         BETA*BETA=XL*XL*D*SH/XK
C                   WHERE D=DENSITY
C                         SH=SPECIFIC HEAT
C         RES=RESISTANCE OF RADIATION PATH WHENEVER APPLICABLE.
C
C         M=NUMBER OF LAYER THE SLAB IS COMPOSED
C
C         W=ARRAY CONTAINING THE FREQUENCIES AT WHICH THE FUNCTIONS
C           ARE EVALUATED
C
C         A=CONTAINS THE VALUES OF THE FUNCTIONS AT S=IW FOR THE
C           VARIOUS FREQUENCIES ON RETURN FROM THE SUBROUTINE.
C
      DOUBLE PRECISION RR(20).BETA(20).RES(20).XL(20).XK(20).D(20).
     1SH(20).AA.BB.CC.DD.EE.FF.P.R.ALPHA.PHI.PI.ARG1.ARG2.TEMP.W(6)
      COMPLEX*16 A(6.2.2).MM(2.2).MMM(2.2).MMMM(2.2)
      PI=3.14159265
      DO 60 J=1.LW
      DO 10 I=1.M
      R=RR(I)
      IF(W(J).NE.0.0.AND.XL(I).NE.0.0) GO TO 5
      MM(1.1)=(1.0D0.0.0D0)
      ARG2=0.0
      MM(1.2)=DCMPLX(R.ARG2)
      MM(2.1)=(0.0D0.0.0D0)
      GO TO 6
    5 P=2.0*PI/W(J)
      ALPHA=XK(I)/D(I)/SH(I)
      PHI=DSQRT(PI*XL(I)*XL(I)/ALPHA/P)
      AA=DSIN(PHI)
      BB=DCOS(PHI)
      CC=DEXP(PHI)
      DD=DEXP(-PHI)
      EE=(CC-DD)/2.0
      FF=(CC+DD)/2.0
      ARG1=FF*BB
      ARG2=EE*AA
      MM(1.1)=DCMPLX(ARG1.ARG2)
      ARG1=RR(I)*(FF*AA+EE*BB)/2.0/PHI
      ARG2=RR(I)*(FF*AA-EE*BB)/2.0/PHI
      MM(1.2)=DCMPLX(ARG1.ARG2)
      TEMP=2.0*ARG1*PHI*PHI/RR(I)/RR(I)
      ARG1=-ARG2*2.0*PHI*PHI/RR(I)/RR(I)
      ARG2=TEMP
      MM(2.1)=DCMPLX(ARG1.ARG2)
    6 MM(2.2)=MM(1.1)
      IF(RES(I).EQ.0.0) GO TO 7
      MM(2.1)=(MM(2.1)*RES(I)+2.0*MM(1.1)-2.0)/(MM(1.2)+RES(I))
      MM(1.1)=(MM(1.1)*RES(I)+MM(1.2))/(MM(1.2)+RES(I))
```

B7. Continued

```
      MM(1,2)=(MM(1,2)*RES(I))/(MM(1,2)+RES(I))
      MM(2,2)=MM(1,1)
    7 IF(I.EQ.1) GO TO 20
      DO 30 K=1,2
      DO 30 L=1,2
      MMMM(K,L)=(0.0,0.0)
      DO 30 N=1,2
   30 MMMM(K,L)=MMMM(K,L)+MM(N,L)*MMM(K,N)
      DO 40 K=1,2
      DO 40 L=1,2
   40 MMM(K,L)=MMMM(K,L)
      GO TO 10
   20 DO 50 K=1,2
      DO 50 L=1,2
   50 MMM(K,L)=MM(K,L)
   10 CONTINUE
      DO 70 K=1,2
      DO 70 L=1,2
   70 A(J,K,L)=MMM(K,L)
   60 CONTINUE
      RETURN
      END
```

B8. Subroutine POLYM.

```
      SUBROUTINE POLYM(A,B,N,M)
C
C     THIS SUBROUTINE FINDS THE PRODUCT OF TWO POLYNOMIALS OF ORDER
C     N AND M RESPECTIVELY.(N=ORDER OF NEW POLYNOMIAL A ON RETURN).
C
      DOUBLE PRECISION A(900),B(900),C(900)
      K=N+M
      K=MIN0(K,899)
      KK=K+1
      DO 10 I=1,900
   10 C(I)=0.0
      DO 25 I=1,KK
      KKK=I
      L=N+1
      L=MIN0(I,L)
      J=I-M
      J=MAX0(1,J)
      DO 20 NN=J,L
      INN=I-NN+1
   20 C(I)=C(I)+A(NN)*B(INN)
      IF(I.LT.5)GO TO 25
      IF(DABS(C(I)).LT.0.1D-12) GO TO 35
   25 CONTINUE
   35 KK=KKK
      DO 30 I=1,900
   30 A(I)=C(I)
      N=KK-1
      RETURN
      END
```

B9. Subroutine SOLVN.

```
C     IDENTIFICATION - CLPG 101  SOLVD
C
C     PURPOSE
C     MATRIX INVERSION AND SOLUTION OF LINEAR EQUATIONS
C
C     AUTHOR / DATE
C     NRC COMPUTATION CENTRE / 1968
C
C     SOURCE LANGUAGE
C     IBM SYSTEM 360 FORTRAN IV (DOUBLE PRECISION)
C
C     REFERENCES
C     SEE NRC PROGRAMMER'S MANUAL - PROGRAM LIBRARY CHAPTER
C
C     CALLING SEQUENCE
C     CALL SOLVD (X,IX.M.N.PREC.DET.TEST)
C
C     ON ENTRY
C         X    - A TWO DIMENSION ARRAY CONTAINING THE MATRIX AND
C                OPTIONALLY SOME RIGHT HAND SIDES
C         IX   - THE FIRST DIMENSION OF X
C         M    - THE NO. OF ROWS IN THE MATRIX
C                M .LE. THE DIMENSION OF I1 AND I2
C         N    - THE NO. OF COLUMNS IN THE MATRIX
C                N = M + (NO. OF RIGHT HAND SIDES)
C         PREC - A PARAMETER USED TO TEST FOR A NEARLY SINGULAR MATRIX.
C                IF A PIVOT .LE. |PREC|*(MATRIX NORM) IT IS CONSIDERED
C                TO BE 0 AND THE INVERSION IS STOPPED. IF PREC=0 THEN IT
C                IS ASSUMED TO BE .5D-14
C
C     ON RETURN
C         X    - THE INVERSE MATRIX HAS REPLACED THE ORIGINAL
C                AND THE RIGHT HAND SIDES (IF ANY) HAVE BEEN REPLACED BY
C                THEIR CORRESPONDING SOLUTIONS
C         DET  - THE DETERMINANT
C         TEST - =0 IF INVERSE AND SOLUTIONS ARE CALCULATED O.K.
C                NE 0 IF MATRIX IS SINGULAR. IN WHICH CASE NO INVERSE
C                     OR SOLUTIONS HAVE BEEN FOUND. IN THIS CASE
C                     TEST=|PREC|*(MATRIX NORM)
C
      SUBROUTINE SOLVD (X.IX.M.N.PREC.DET.TEST)
C
      INTEGER*2 I1(255). I2(255)
      REAL*8 X(IX.2).T.DET.BIG.PREC.TEST.PIV.TEMP.DSQRT.DABS
      EQUIVALENCE (BIG.TEMP.PIV)
C
C     INITIALIZATION
C
      DET = 1.D0
      TEMP = DABS(PREC)
      IF (TEMP .EQ. 0.D0)  TEMP = 0.5D-14
      TEST = 0.D0
      DO 1 I = 1.M
      I2(I) = 0
      DO 1 J = 1.M
    1 TEST = TEST + X(I.J) * X(I.J)
      TEST = TEMP * DSQRT(TEST) / M
C
```

B9. Continued

```
C      SEARCH FOR NEXT PIVOT, AVOIDING ROWS AND COLUMNS WHICH ALREADY
C      CONTAIN A PIVOT.
C
       DO 9 K = 1,M
       BIG = 0.D0
       DO 3 I = 1,M
       IF (I2(I) .NE. 0) GO TO 3
       DO 2 J = 1,M
       IF (I2(J) .NE. 0) GO TO 2
       T =DABS(X(I,J))
       IF (T .LE. BIG) GO TO 2
       BIG = T
       IROW = I
       JCOL = J
     2 CONTINUE
     3 CONTINUE
       IF (BIG .LE. TEST) RETURN
C
C      RECORD POSITION OF PIVOT THEN MOVE PIVOTAL ROW SO PIVOT LIES ON
C      THE DIAGONAL. SCALE PIVOTAL ROW.
C
       I1(K) = JCOL
       I2(JCOL) = IROW
       IF (JCOL .EQ. IROW) GO TO 6
       DO 5 J = 1,N
       TEMP = X(IROW,J)
       X(IROW,J) = X(JCOL,J)
     5 X(JCOL,J) = TEMP
       DET = -DET
     6 DET = DET * X(JCOL,JCOL)
       PIV = 1.D0/X(JCOL,JCOL)
       DO 7 J = 1,N
       IF (J .NE. JCOL)  X(JCOL,J) = PIV * X(JCOL,J)
     7 CONTINUE
       X(JCOL,JCOL) = PIV
C
C      ELIMINATE REMAINING ROWS.
C
       DO 9 I = 1,M
       IF (I .EQ. JCOL)  GO TO 9
       PIV = -X(I,JCOL)
       DO 8 J = 1,N
       IF (J .NE. JCOL)  X(I,J) = X(I,J) + PIV * X(JCOL,J)
     8 CONTINUE
       X(I,JCOL) = PIV * X(JCOL,JCOL)
     9 CONTINUE
C
C      UNSCRAMBLE THE COLUMNS OF THE INVERSE ACCORDING TO THE ORIGINAL
C      POSITIONS OF THE PIVOTS.
C
       DO 11 K = 1,M
       I = M+1 - K
       JCOL = I1(I)
       IROW = I2(JCOL)
       IF (IROW .EQ. JCOL)  GO TO 11
       DO 10 I = 1,M
       TEMP = X(I,IROW)
       X(I,IROW) = X(I,JCOL)
    10 X(I,JCOL) = TEMP
    11 CONTINUE
       TEST = 0.D0
       RETURN
       END
```

B10. Subroutine AIRCAV.

```
      SUBROUTINE AIRCAV(RESI,EE1,EE2,ZZZ)
      DOUBLE PRECISION SA(250,100),AVH,A1(120),A2(120),A3(120),AZ(120),
     1B1(120),B2(120),B3(120),BZ(120),C1(120),C2(120),C3(120),CZ(120),
     2D1(120),D2(120),D3(120),DZ(120)
      COMMON A1,A2,A3,AZ,B1,B2,B3,BZ,C1,C2,C3,CZ,D1,D2,D3,DZ,
     1KXX,KXY,KXZ,KYX,AVH,SA
      AVSO=0
      AVTE=0
      DO 3013 I=7,17
      AVSO=SNGL(AVSO+SA(89,I)+SA(109,I))
      AVTE=SNGL(AVTE+SA(20,I))
 3013 CONTINUE
      AVSO=AVSO/22
      AVTE=AVTE/11
      DT=ABS(AVSO-AVTE)
      ATC=(AVSO+AVTE)/2
      DTL3=DT*(AVH**3)
 3015 XXX=DLOG10(DT*(AVH**3))
      IF (ZZZ.LT.2.0) GO TO 2
      IF(DTL3.GT.10) GO TO 2019
      AA0=-1.77
      AA1=0
      AA2=0
      AA3=0
      GO TO 2020
 2019 AA0=-1.745
      AA1=-0.0028
      AA2=.0029
      AA3=.0008
      GO TO 2020
    2 AA0=-1.5904
      AA1=0.2824
      AA2=0.0
      AA3=0.0
 2020 YYY=AA0+(AA1*XXX)+(AA2*(XXX**2))+(AA3*(XXX**3))
      ZZZ=EXP(YYY)
      IF(ZZZ.LT.0.2.AND.ZZZ.GT.0.3) GO TO 2021
      HC=ZZZ*((1+0.00035*(DT-50))/AVH)
      GO TO 2022
 2021 IF(ZZZ.LT.0.2) GO TO 2023
      HC=ZZZ*((1-.001*(DT-50))/AVH)
      GO TO 2022
 2023 HC=ZZZ*((1+.0017*(DT-50))/AVH)
 2022 HR=.00686*(((ATC+460)/100)**3)
      RESI=1/(HC+(1/((1/EE1)+(1/EE2)-1))*HR)
      RETURN
      END
```

B11. Subroutine START.

```
      SUBROUTINE START(ICOMP,ICOM,POL3,POL4,POL5,POL6,TEM1,TEM2,TEP2,
     1AM1,AM2,EW,AW,ARCER,COEF1,IZ,COEFI)
      DIMENSION POL3(100),POL4(100),POL5(100),POL6(100),TEM1(120),TEM2(1
     220),AM1(150),AM2(150),TE(120),TF(120),COEFI(3),Q1(7),Q2(7),Q(7)
     3,QQ(7)
      DOUBLE PRECISION SA(250,100),AVH,A1(120),A2(120),A3(120),AZ(120),
     3B1(120),B2(120),B3(120),BZ(120),C1(120),C2(120),C3(120),CZ(120),
     4D1(120),D2(120),D3(120),DZ(120)
      COMMON A1,A2,A3,AZ,B1,B2,B3,BZ,C1,C2,C3,CZ,D1,D2,D3,DZ,
     5KXX,KXY,KXZ,KYX,AVH,SA
      GO TO (41,42,43,44),ICOMP
   41 N=KXX-1
      COEF2=COEFI(2)
      GO TO 55
   42 N=KXY-1
      COEF2=COEFI(3)
      GO TO 55
   43 N=KXZ-1
      COEF2=COEFI(1)
      GO TO 55
   44 N=KYX-1
      COEF2=COEFI(2)
   55 ICOM=ICOM+1
      DO 40 I=1,7
      Q1(I)=0.
      Q2(I)=0.
   40 CONTINUE
      DO 580 M=1,7
      S22=0
      S23=0
      SUM1=0
      SUM2=0
      SUM3=0
      SUM4=0
      SUM5=0
      SUM6=0
      S1=0
      S2=0
      R1=0
      R2=0
      DO 912 I=1,N
      J=I+1
      PRO1=TEM1(I)*POL3(J)
      PRO2=TEM2(I)*POL4(J)
      PRO3=TEM2(I)*POL5(J)
      PRO4=TEM1(I)*POL4(J)
      PRO5=Q1(I)*POL6(J)
      PRO6=Q2(I)*POL6(J)
      SUM1=SUM1+PRO1
      SUM2=SUM2+PRO2
      SUM3=SUM3+PRO3
      SUM4=SUM4+PRO4
      SUM5=SUM5+PRO5
      SUM6=SUM6+PRO6
  912 CONTINUE
      TEMP2=TEP2
      TEMP1=0
      TEP1=0
```

B11. Continued

```
  916 J=M
      S22=.1714E-8*((460+TEMP1)**4)
      S23=.1714E-8*((460+SA(IZ-2,M))**4)
      GO TO (833,834,821,832,837,835,836,833,834,831,832),ICOM
  831 R1=(EW*S22)
      S1=(AW*SA(47,J))+(EW*S23)
      GO TO 1057
  832 R1=(EW*S22)
      S1=(AW*SA(67,J))+(EW*S23)
      GO TO 1057
  833 R1=(EW*S22)
      S1=(AW*SA(7,J))+(EW*S23)
      GO TO 1057
  834 R1=(EW*S22)
      S1=(AW*SA(27,J))+(EW*S23)
      GO TO 1057
  835 R1=ER*S22
      S1=(AR*SA(107,J))+(ER*S23)
      GO TO 1057
  836 R1=ER*S22
      S1=(AR*SA(127,J))+(ER*S23)
      GO TO 1057
  837 R1=ER*S22
      S1=(AR*SA(87,J))+(ER*S23)
 1057 TEMP1=(R1-(COEF1*SA(IZ-2,M))-(POL4(1)*TEMP2)-S1+SUM1-SUM2-SUM5)/
     1(-COEF1-POL3(1))
      IF(ABS(TEMP1-TEP1).LE.0.05) GO TO 918
      TEP1=TEMP1
      TEMP2=(R2-(COEF2*AM2(M))-(POL4(1)*TEP1)-S2+SUM6+SUM3-SUM4)/(-COEF2
     1-POL5(1))
      GO TO 916
  918 QQ2=-SUM3+SUM4-(POL5(1)*TEMP2)+(POL4(1)*TEMP1)-SUM6
      QQ1=SUM1-SUM2+(POL3(1)*TEMP1)-(POL4(1)*TEMP2)-SUM5
      C8=COEF1*(SA(IZ-2,M)-TEMP1)
      C9=COEF2*(TEMP2-AM2(M))
      SA(IZ,M)=R1
      SA(IZ+1,M)=S1
      SA(IZ+2,M)=C8
      SA(IZ+3,M)=QQ1
      SA(IZ+4,M)=TEMP1
      SA(IZ+5,M)=TEMP2
      SA(IZ+6,M)=QQ2
      SA(IZ+7,M)=C9
      SA(IZ+8,M)=AM2(M)
      TEP2=TEMP2
      TE(1)=TEMP1
      NN=N-1
      DO 914 I=1,NN
      TE(I+1)=TEM1(I)
  914 CONTINUE
      DO 921 I=1,N
      TEM1(I)=0
  921 CONTINUE
      DO 915 I=1,N
      TEM1(I)=TE(I)
  915 CONTINUE
      TF(1)=TEMP2
      DO 819 I=1,N
      TF(I+1)=TEM2(I)
  819 CONTINUE
```

B11. Continued

```
      DO 822 I=1,N
      TEM2(I)=0
  822 CONTINUE
      DO 23 I=1,N
      TEM2(I)=TF(I)
   23 CONTINUE
      Q(1)=QQ1
      QQ(1)=QQ2
      DO 4 I=1,NN
      Q(I+1)=Q1(I)
      QQ(I+1)=Q2(I)
    4 CONTINUE
      DO 6 I=1,N
      Q1(I)=Q(I)
      Q2(I)=QQ(I)
    6 CONTINUE
  580 CONTINUE
      RETURN
      END
```

B12. Subroutine FLUX.

```
      SUBROUTINE FLUX(M.ICOMP.ICON.POL3.POL4.POL5.POL6.
     1AM1.AM2.EW.AW.AR.ER.COEF1.IZ.COEFI)
      DIMENSION POL3(100).POL4(100).POL5(100).POL6(100).TEM1(120).TEM2(1
     220).AM1(150).AM2(150).COEFI(3)
      DOUBLE PRECISION SA(250.100).AVH.A1(120).A2(120).A3(120).AZ(120).
     3B1(120).B2(120).B3(120).BZ(120).C1(120).C2(120).C3(120).CZ(120).
     4D1(120).D2(120).D3(120).DZ(120)
      COMMON A1.A2.A3.AZ.B1.B2.B3.BZ.C1.C2.C3.CZ.D1.D2.D3.DZ.
     5KXX.KXY.KXZ.KYX.AVH.SA
      GO TO (41.42.43.44).ICOMP
   41 N=KXX-1
      COEF2=COEFI(2)
      GO TO 55
   42 N=KXY-1
      COEF2=COEFI(3)
      GO TO 55
   43 N=KXZ-1
      COEF2=COEFI(1)
      GO TO 55
   44 N=KYX-1
      COEF2=COEFI(2)
   55 ICON=ICON+1
      S22=0
      S23=0
      SUM1=0
      SUM2=0
      SUM3=0
      SUM4=0
      SUM5=0
      SUM6=0
      S1=0
      S2=0
      R1=0
      R2=0
      DO 912 I=1.N
      J=I+1
      PRO1=SA(IZ+4.M-I)*POL3(J)
      PRO2=SA(IZ+5.M-I)*POL4(J)
      PRO3=SA(IZ+5.M-I)*POL5(J)
      PRO4=SA(IZ+4.M-I)*POL4(J)
      PRO5=SA(IZ+3.M-I)*POL6(J)
      PRO6=SA(IZ+6.M-I)*POL6(J)
      SUM1=SUM1+PRO1
      SUM2=SUM2+PRO2
      SUM3=SUM3+PRO3
      SUM4=SUM4+PRO4
      SUM5=SUM5+PRO5
      SUM6=SUM6+PRO6
  912 CONTINUE
      TEMP2=SA(IZ+5.M-1)
      TEMP1=SA(IZ+4.M-1)
      TEP1=TEMP1
  916 J=M
      S22=.1714E-8*((460+TEMP1)**4)
      S23=.1714E-8*((460+SA(IZ-2.M))**4)
      GO TO (833.834.831.832.837.835.836.833.834.831.832).ICON
  831 R1=(EW*S22)
      S1=(AW*SA(47.J))+(EW*S23)
```

B12. Continued

```
      GO TO 1057
  832 R1=(EW*S22)
      S1=(AW*SA(67,J))+(EW*S23)
      GO TO 1057
  833 R1=(EW*S22)
      S1=(AW*SA(7,J))+(EW*S23)
      GO TO 1057
  834 R1=(EW*S22)
      S1=(AW*SA(27,J))+(EW*S23)
      GO TO 1057
  835 R1=ER*S22
      S1=(AR*SA(107,J))+(ER*S23)
      GO TO 1057
  836 R1=ER*S22
      S1=(AR*SA(127,J))+(ER*S23)
      GO TO 1057
  837 R1=ER*S22
      S1=(AR*SA(87,J))+(ER*S23)
 1057 TEMP1=(R1-(COEF1*SA(IZ-2,M))-(POL4(1)*TEMP2)-S1+SUM1-SUM2-SUM5)/
     1(-COEF1-POL3(1))
      IF(ABS(TEMP1-TEP1).LE.0.05) GO TO 918
      TEP1=TEMP1
      TEMP2=(R2-(COEF2*AM2(M))-(POL4(1)*TEP1)-S2+SUM6+SUM3-SUM4)/(-COEF2
     1-POL5(1))
      GO TO 916
  918 Q2=-SUM3+SUM4-(POL5(1)*TEMP2)+(POL4(1)*TEMP1)-SUM6
      Q1=SUM1-SUM2+(POL3(1)*TEMP1)-(POL4(1)*TEMP2)-SUM5
      C8=COEF1*(SA(IZ-2,M)-TEMP1)
      C9=COEF2*(TEMP2-AM2(M))
      SA(IZ,M)=R1
      SA(IZ+1,M)=S1
      SA(IZ+2,M)=C8
      SA(IZ+3,M)=Q1
      SA(IZ+4,M)=TEMP1
      SA(IZ+5,M)=TEMP2
      SA(IZ+6,M)=Q2
      SA(IZ+7,M)=C9
      SA(IZ+8,M)=AM2(M)
      RETURN
      END
```

B13. Subroutine HPROD.

```
      SUBROUTINE HPROD(HOGWT.HOGS.MGMT.M.AM2.Q,G,MGMTS)
      DIMENSION AM2(150).HOGWT(10).HOGS(10).Q(120).G(120)
      REAL MOIST.MOIS,LH.MGMT.MGMTS
      TSH=0.
      TMOIS=0.
   20 DO 4 I=1.10
      IF(HOGWT(I).EQ.0.0)GO TO 10
      TH=10.**(2.477+0.034*ALOG10(HOGWT(I))-0.00577*AM2(M)+0.148*(ALOG10
     1(HOGWT(I)))**2+0.000071*AM2(M)**2-0.00313*AM2(M)*ALOG10(HOGWT(I)))
      MOIST=10.**(-0.961+0.00291*HOGWT(I)-0.00785*AM2(M)-0.0000146*AM2(M
     1)*HOGWT(I)-0.0000029*HOGWT(I)**2+0.0001375*AM2(M)**2)*MGMT
   30 LH=1040.*MOIST
      SH=(TH-LH)*MGMTS
      MOIS=MOIST*HOGS(I)
      SHE=SH*HOGS(I)
      TSH=TSH+SHE
    4 TMOIS=TMOIS+MOIS
   10 Q(M)=TSH
      G(M)=TMOIS
   40 RETURN
      END
```

B14. Subroutine WALL.

```
      SUBROUTINE WALL(M,UA,AM1,AM2,SC,AEWA,ATWA,ASWA,AWWA,AEDO,ATDO,
     1ASDO,AWDO,AEWI,ATWI,ASWI,AFLO,ARO1,ARO2,ARO3,WAL,DOR,FLO,ROOF,ROF,
     2WIN,QSUM)
      DIMENSION AM1(150),AM2(150),WAL(120),DOR(120),FLO(120),ROOF(120),
     3ROF(120),WIN(120),QSUM(120),SS(120),SW(120),SE(120),SN(120)
      DOUBLE PRECISION SA(250,100),AVH,A1(120),A2(120),A3(120),AZ(120),
     4B1(120),B2(120),B3(120),BZ(120),C1(120),C2(120),C3(120),CZ(120),
     5D1(120),D2(120),D3(120),DZ(120)
      COMMON A1,A2,A3,AZ,B1,B2,B3,BZ,C1,C2,C3,CZ,D1,D2,D3,DZ,
     6KXX,KXY,KXZ,KYX,AVH,SA
      N=M
      I=M
      UAV=UA*(AM1(I)-AM2(I))
      SS(M)=((SC*SA(8,N))+UAV)*ASWI
      SW(M)=((SC*SA(28,N))+UAV)*AWWI
      SE(M)=((SC*SA(48,N))+UAV)*AEWI
      SN(M)=((SC*SA(68,N))+UAV)*ATWI
      WIN(M)=SE(M)+SW(M)+SN(M)+SS(M)
      WAL(M)=(SA(58,M)*(AEWA-AEDO-AEWI))+(SA(78,M)*(ATWA-ATDO-ATWI))+(SA
     1(18,M)*(ASWA-ASDO-ASWI))+(SA(38,M)*(AWWA-AWDO-AWWI))
      DOR(M)=(SA(198,M)*AEDO)+(SA(218,M)*ATDO)+(SA(178,M)*AWDO)+(SA(158,
     1M)*ASDO)
      ROF(M)=(SA(118,M)*ARO1)+(SA(98,M)*ARO2)
      ROOF(M)=ARO3*SA(138,M)
      FLO(M)=AFLO*0.38*(AM1(M)-AM2(M))
      QSUM(M)=WAL(M)+DOR(M)+FLO(M)+ROF(M)+ROOF(M)+WIN(M)
      RETURN
      END
```

B15. Subroutine VENTIL.

```
      SUBROUTINE VENTIL(M,AM2 ,AM1,TW1,B,QSUM,
     1SENS,WM,RH,C4,C5,RH1,SUP,SUMQ,RH2)
      EXTERNAL PICE,PH2O
      DIMENSION AM2(150),AM1(150),TW1(150),
     2QSUM(120),SENS(120),WM(120),C4(120),C5(120),
     3RH1(120),SUP(120),SUMQ(120),RH2(120),B(150)
      HG2=1061.+0.444*AM2(M)
      HG3=1061.+0.444*AM1(M)
      IF (TW1(M).GT.32.) GO TO 949
      CALL PICE(M,TW1,PW1)
      GO TO 951
  949 CALL PH2O(M,TW1,PW1)
  951 IF (AM2(M).GT.32.) GO TO 222
      CALL PICE(M,AM2,PW2)
      GO TO 223
  222 CALL PH2O(M,AM2,PW2)
  223 IF (AM1(M).GT.32.) GO TO 101
      CALL PICE(M,AM1,PW3)
      GO TO 888
  101 CALL PH2O(M,AM1,PW3)
  888 E1=PW1-((B(M)-PW1)*(AM1(M)-TW1(M))/(2800-1.3*TW1(M)))
      W1=4354*E1/(B(M)-E1)
      V1=(((.754*(AM1(M)+459.7))/B(M))*(1+(W1/4360)))
      W1=W1/7000.0
      H1=(.24*AM1(M))+(W1*HG3)
      SUMQ(M)=QSUM(M)+SENS(M)
      H2=(.24*AM2(M))+(W1*HG2)
      WS=(.622*PW2)/(B(M)-PW2)
      U=((RH*B(M))-(RH*PW2))/((100.0*B(M))-(RH*PW2))
      W2=U*WS
      C4(M)=(WM(M)*V1)/(60*(W2-W1))
      C5(M)=(SUMQ(M)*V1)/(60*(H2-H1))
      W4=((WM(M)*V1)/(60.0*C5(M)))+W1
      IF(C5(M).LE.0) W4=WS
      IF(C5(M).LE.0) C5(M)=0
      U=W4/WS
      IF(U.LE.1.0) GO TO 843
      U=1.0
  843 RH1(M)=(100.0*U)/(1-((1-U)*(PW2/B(M))))
      WSS=(.622*PW3)/(B(M)-PW3)
      U=W1/WSS
      IF(U.LE.1.0) GO TO 844
      U=1.0
  844 RH2(M)=(100.0*U)/(1-((1-U)*(PW3/B(M))))
      SUP(M)=((60.0*C4(M)*(H2-H1))/V1)-SUMQ(M)
      RETURN
      END
```

B16. Subroutine PICE.

```
      SUBROUTINE PICE(I.T.PP)
      DIMENSION T(150)
      C=(T(I)-32.)*(5./9.)
      A=C+273.16
      TT=273.16/A
      P=10.**(-9.096936*(TT-1.)-3.56654*ALOG10(TT)+0.876817*(1.-(1./TT))
     1-2.219598)
      PP=P*29.921
      RETURN
      END
```

B17. Subroutine PH20.

```
      SUBROUTINE PH2O(I,T,PP)
      DIMENSION T(150)
      C=(T(I)-32.)*(5./9.)
      A=C+273.16
      TT=273.16/A
      P=10.**(10.79586*(1.-TT)+5.02808*ALOG10(TT)+1.50474E-4*(1.-10**
     1(-8.29692*((1./TT)-1.)))+0.42873E-3*(10.**(4.76955*(1.-TT))-1.)
     2-2.219598)
      PP=P*29.921
      RETURN
      END
```

APPENDIX C: PROGRAM VARIABLE NAMES AND UNITS

C1. MAIN Variable Names and Units.

AEDO = area of east doors, ft^2,

AEWA = area of east walls, ft^2,

AEWI = area of east windows, ft^2,

AFLO = perimeter of floor, ft,

AM1 = outside dry-bulb temperature, ^{o}F,

AM2 = inside dry-bulb temperature, ^{o}F,

AN = number of animals confined,

AR = absorptivity factor for outside roof surface,

ARO1 = area of roof slope #1, ft^2,

ARO2 = area of roof slope #2, ft^2,

ARO3 = area of horizontal roof, ft^2,

ASDO = area of south doors, ft^2,

ASWA = area of south walls, ft^2,

ASWI = area of south windows, ft^2,

ATDO = area of north doors, ft^2,

ATTD = attic dry-bulb temperature, ^{o}F,

ATTW = attic wet-bulb temperature, ^{o}F,

ATWA = area of north walls, ft^2,

ATWI = area of north windows, ft^2,

AVH = average thickness of the air cavity, in,

AW = absorptivity factor for outside wall surface,

AWDO = area of west doors, ft^2,

AWWA = area of west walls, ft^2,

AWWI = area of west windows, ft^2,

A1 = z-transfer function coefficient, A, for wall,

A2 = z-transfer function coefficient, B, for wall,

A3 = z-transfer function coefficient, C, for wall,

AZ = z-transfer function coefficient, D, for wall,

B = barometric pressure, in Hg,

B1 = z-transfer function coefficient, A, for pitched roof,

B2 = z-transfer function coefficient, B, for pitched roof,

B3 = z-transfer function coefficient, C, for pitched roof,

BZ = z-transfer function coefficient, D, for pitched roof,

LO
CA } = location,
TX

CCC = trial-and-error method indicator,

CHANGE = increment of change for inside dry bulb temperature, °F,

COEF1 = outside film conductance, BTU/(ft^2)(hr)(°F),

COEFI = inside film conductance, BTU/(ft^2)(hr)(°F),

C1 = z-transfer function coefficient, A, for horizontal roof,

C2 = z-transfer function coefficient, B, for horizontal roof,

C3 = z-transfer function coefficient, C, for horizontal roof,

CZ = z-transfer function coefficient, D, for horizontal roof,

C4 = ventilation rate required to remove moisture, cfm,

C5 = ventilation rate required to remove resultant heat load, cfm,

DAY } = day of month,

DECL
DECLIN = declination, degrees,

DIFF2 = error in ventilation rate calculation, cfm, DOR = total heat flow through doors, BTU/hr,

DST = daylight saving time,

D1 = z-transfer function coefficient, A, for door,

D2 = z-transfer function coefficient, B, for door,

D3 = z-transfer function coefficient, C, for door,

DZ = z-transfer function coefficient, D, for door,

EE1 = emissivity factor for upper surface of attic space,

EE2 = emissivity factor for lower surface of attic space,

ER = emissivity factor for outside roof surface,

ERROR = accuracy desired for ventilation rate calculation,

ET

} = equation of time, min,

EQTIME

EW = emissivity factor for outside wall surface,

FLO = total heat flow through floor, BTU/hr,

G = moisture production of the confined animals, lb moisture/hr,

HEATR = heat load, BTU/hr,

HOGWT = average hog weight of a group of hogs, lb,

HOGS = number of hogs of a given weight,

IATTIC = ingoing temperature indicator,

ICOM = surface orientation counter,

ICOMP = surface indicator,

IZ = counter for printing output,

KXX = number of z-transfer function coefficients for wall,

KXY = number of z-transfer function coefficients for pitched roof,

KXZ = number of z-transfer function coefficients for horizontal roof,

KYX = number of z-transfer function coefficients for door,

MGMT = management factor for moisture production, MGMTS = management for sensible heat production,

OUT = error in ventilation rate calculation, cfm,

PERC = error in ventilation rate calculation, %,

PLAT = latitude of location, degrees,

PLONG = longitude of location, degrees,

POL3 = z-transfer function coefficient, A,

POL4 = z-transfer function coefficient, B,

POL5 = z-transfer function coefficient, C,

POL6 = z-transfer function coefficient, D,

Q = sensible heat production of confined animals, BTU/hr,

QSUM = total heat flow through all structural components, BTU/hr,

RH = relative humidity for ventilation rate required to remove moisture,

RH1 = relative humidity for ventilation rate required to remove resultant heat load,

RH2 = outside relative humidity,

RMONTH = month,

ROF = total heat flow through pitched roof, BTU/hr,

ROOF = total heat flow through horizontal roof, BTU/hr,

SA = program output parameters,

SB = row names for program output parameters,

SC = shading coefficient,

SENS = total sensible heat production within the building, BTU/hr,

SUMQ = resultant heat load in the building, BTU/hr,

SUP = heat load necessary to ensure a ventilation rate required to remove moisture, BTU/hr,

TEM1 = outside surface temperature, ^{o}F, TEM2 = inside surface temperature, ^{o}F,

TNT = simulation time, days,

TTT = decreasing temperature indicator for trial-and-error method,

TW1 = outside wet-bulb temperature, ^{o}F,

TZN = time zone number,

UA = heat transfer coefficient for windows installed, BTU/ (ft^2) $(hr)(^{o}F)$,

UUU = increasing temperature indicator for trial-and-error method,

VENT = ventilation rate within the building, cfm.

WAL = total heat flow through walls, BTU/hr,

WALLA = wall azimuth, degrees,

WALLT = wall tilt, degrees,

WIN = total heat flow through windows, BTU/hr,

WM = moisture production within the confinement unit, lb moisture/hr,

YEAR = year,

X = month,

Z = year.

C2. SOLAR Variable Names and Units.

AA = apparent solar constant, BTU/(hr)(ft^2),

ADIN = absorption factor of diffuse radiation through inner window pane,

ADOUT = absorption factor of diffuse radiation through outer window pane,

AIN = polynomial coefficient for use in calculation of absorption factor of inner window pane,

ALPHA = directional cosine of normal to surface, vertical reference axis,

AOIN = absorption factor of direct radiation through inner window pane,

AOOUT = absorption factor of direct radiation through outer window pane,

AOUT = polynomial coefficient for use in calculation of absorption factor of outer window pane,

ARO = parameter a/ho,

where a = absorptance of the surface for solar radiation, and

ho = coefficient of heat transfer by radiation and convection at the outer surface, BTU/(hr)(ft^2)(^oF),

B = atmospheric extinction coefficient,

BETA = directional cosine of normal to surface, reference axis horizontal to west,

BLAT = latitude, radians,

C = sky diffuse factor,

LO
CA = location,
TX

CCM = cloud cover modifier,

CN = clearness number,

COSINC = cosine of the angle of incidence,

COSSS
COSW = directional cosines of direct solar beam,
COSZ

CT = cloud type,

D = day of year,

DAY = day of year,

DEC = declination angle, radians,

DECL
DECLIN = declination angle, degrees,

DD = solar heat gain factor for direct solar radiation, BTU/(hr)(ft^2),

DDD = solar heat gain factor for diffuse solar radiation, BTU/(hr)(ft^2),

DST = daylight saving time,

EA
EB = surface indication,
EC

ET
EQTIME = equation of time, hr,

GAMMA = directional cosine of normal to surface, reference axis horizontal to south, GRD = intensity of ground diffuse radiation incident on surface, BTU/(hr)(ft^2),

HA = absolute value of hour angle, radians,

HAD = hour angle, degrees,

HHSUN = hour angle for sunrise and sunset, radians,

HO = coefficient of heat transfer by radiation and convection at the outer surface, BTU/(hr)(ft^2)(^{o}F),

HSUN = hour angle for sunrise and sunset, degrees,

ICNT = day counter,

ISTOP = surface counter,

NII = inward flowing fraction of the radiation absorbed by the inner window pane,

NIO = inward flowing fraction of the radiation absorbed by the outer window pane,

OT = outside dry-bulb temperature, ^{o}F,

OW = outside wet-bulb temperature, ^{o}F,

PLAT = latitude of location,degrees,

PLONG = longitude of location,degrees,

R = ground reflectivity,

RMONTH = month,

SA = matrix containing the solar output,

SALT = solar altitude, radians,

SKY = intensity of ground diffuse radiation incident on surface, BTU/(hr)(ft^2),

SRT = sunrise time, hr,

SST = sunset time, hr,

ST = solar output parameters,

T = polynomial coefficient for use in calculation of transmission factor of window,

TC = total cloud cover,

TD = transmission factor of diffuse radiation for window,

TNT = simulation time period,

TO = transmission factor of direct radiation for window,

TZN = time zone,

U = month,

WA = surface azimuth, radians,

WALLA = surface azimith, degrees,

WALLT = surface tilt, degrees,

WT = surface tilt, radians,

X = day of month, and

Y = ratio of sky diffuse on vertical surface to sky diffuse on horizontal surface, and

$\left.\begin{matrix}\text{Year}\\ \text{Z}\end{matrix}\right\}$ = year.

C3. AIRCAV Variable Names and Units.

AA0
AA1
AA2 } = values for calculation of the resistance across the air space,
AA3
AA4

ATC = average temperature of the air cavity, ^{o}F,

AVH = thickness of the air space, inches,

AVSO = average sol-air temperature for the roof surface, ^{o}F,

DT = temperature difference across the air space, ^{o}F,

EE1
EE2 } = emissivity factors for the surface facing the air cavity,

RESI = air cavity thermal resistance, ^{o}F per BTU/(hr)(ft^2),

DTL3 = DTL3
HC = h_c
HR = h_r } intermediate variables as presented in the flow chart.
XXX = X
YYY = Y
ZZZ = Z

C4. START and FLUX Variable Names and Units.

AM2 = inside dry-bulb temperature, ^{o}F,

COEFI(1) = inside film conductance for horizontal roof, BTU/(ft^2)(hr)(^{o}F),

COEFI(2) = inside film conductance for walls and doors, BTU/(ft^2)(hr)(^{o}F),

COEFI(3) = inside film conductance for pitched roof, BTU/(ft^2)(hr)(^{o}F),

COEF1 = outside film conductance, BTU/(ft^2)(hr)(^{o}F),

COEF2 = inside film conductance, BTU/(ft^2)(hr)(^{o}F),

C8 = convection at outside surface, BTU/(ft^2)(hr),

C9 = convection at inside surface, BTU/(ft^2)(hr),

ICOM = surface orientation counter,

ICOMP = surface indicator,

KXX = number of z-transfer function coefficients for wall,

KXY = number of z-transfer function coefficients for pitched roof,

KXZ = number of z-transfer function coefficients for horizontal roof,

KYX = number of z-transfer function coefficients for door,

M = time, hr,

POL3 = z-transfer function coefficient, A,

POL4 = z-transfer function coefficient, B,

POL5 = z-transfer function coefficient, C,

POL6 = z-transfer function coefficient, D,

$\left.\begin{array}{l}\text{PRO1}\\ \text{PRO2}\\ \text{PRO3}\\ \text{PRO4}\\ \text{PRO5}\\ \text{PRO6}\end{array}\right\}$ = intermediate variables for calculation of heat flux and surface temperatures (iterative precedure),

$\left.\begin{array}{l}\text{Q1}\\ \text{Q2}\end{array}\right\}$ = heat flux history, BTU/(ft^2)(hr),

QQ1 = outside surface heat flux, BTU/(ft^2)(hr),

QQ2 = inside surface heat flux, BTU/(ft^2)(hr),

R1 = longwave radiation at outside surface, BTU/(ft^2)(hr),

R2 = longwave radiation at inside surface, BTU/(ft^2)(hr),

SA = program output parameters,

$\left.\begin{array}{l}\text{SUM1}\\ \text{SUM2}\\ \text{SUM3}\\ \text{SUM4}\\ \text{SUM5}\\ \text{SUM6}\end{array}\right\}$ = intermediate variables for calculation of heat flux and surface temperature (iterative procedure),

S1 = radiation absorbed by the outside surface (short wave), BTU/(ft^2)(hr),

S2 = radiation absorbed by the inside surface (short wave), BTU/(ft^2)(hr),

$\left.\begin{array}{l}\text{S22}\\ \text{S33}\end{array}\right\}$ = intermediate variables for determination of radiation at each surface,

TEMP1 = outside surface temperature, ^{o}F,

TEMP2 = inside surface temperature, ^{o}F,

$$\left.\begin{array}{l}\text{TEM1}\\ \text{TEM2}\\ \text{TEP1}\\ \text{TEP2}\\ \text{FF}\end{array}\right\}= \text{variables to establish temperature history, } {}^{o}\text{F,}$$

C5. HPROD Variable Names and Units.

AM2 = inside dry-bulb temperature, °F,

G = total moisture production of all confined hogs, lb/hr,

HOGS = number of hogs in a group,

HOGWT = average hog weight of a group of hogs, lb,

LH = latent heat production per hog of a certain weight, BTU/(hog)(hr),

M = time, hr,

MGMT = management factor for moisture production,

MGMTS = management factor for sensible heat production,

MOIS = moisture production of all hogs of a certain weight, lb moisture/hr,

MOIST = moisture production per hog of a certain weight, lb/(hog)(hr),

Q = total sensible heat production of all confined hogs, BTU/hr,

SH = sensible heat production per hog of a certain weight, BTU/(hog)(hr),

SHE = sensible heat production of all hogs of a certain weight, BTU/hr,

TMOIS = total moisture production of all confined hogs, lb/hr,

TSH = total sensible heat production of all confined hogs, BTU/hr, C6. WALL Variable Names and Units.

AEDO = area of east doors, ft^2,

AEWA = area of east walls, ft^2,

AEWI = area of east windows, ft^2,

AFLO = perimeter of floor, ft,

AM1 = outside dry-bulb temperature, ^{o}F,

AM2 = inside dry-bulb temperature, ^{o}F,

ARO1 = area of east roof slope, ft^2,

ARO2 = area of west roof slope, ft^2,

ARO3 = area of horizontal roof, ft^2,

ASDO = area of south doors, ft^2,

ASWA = area of south walls, ft^2,

ASWI = area of south windows, ft^2,

AIDO = area of north doors, ft^2,

ATWA = area of north walls, ft^2,

ATWI = area of north windows, ft^2,

AWDO = area of west doors, ft^2,

AWWA = area of west walls, ft^2,

AWWI = area of west windows, ft^2,

DOR = heat flow through doors, BTU/hr,

FLO = heat flow through floor, BTU/hr,

QSUM = total heat flow through structural components, BTU/hr,

ROF = heat flow through pitched roof, BTU/hr

ROOF = heat flow through horizontal roof, BTU/hr,

SA = program output matrix,

SC = shading coefficient for glass,

SE = heat flow through east windows, BTU/hr, SN = heat flow through north windows, BTU/hr,

SS = heat flow through south windows, BTU/hr,

SW = heat flow through west windows, BTU/hr,

UA = heat transfer coefficient for glass, BTU/(hr)(ft^2)($^{\circ}$F),

UAV = instantaneous rate of heat conduction through windows, BTU/(hr)(ft^2),

WAL = heat flow through walls, BTU/hr,

WIN = heat flow through windows, BTU/hr,

C7. VENTIL Variable Names and Units.

AM1 = incoming dry-bulb temperature, ^{o}F,

AM2 = inside dry-bulb temperature, ^{o}F,

B = barometric pressure, in Hg,

C4 = ventilation rate required to remove moisture load, cfm,

C5 = ventilation rate required to remove heat load, cfm,

E1 = vapor pressure of incoming air, in Hg,

H1 = enthalpy of incoming air at incoming temperature, BTU/lb d.a.,

H2 = enthalpy of incoming air at inside temperature, BTU/lb d.a.,

HG2 = enthalpy of saturated water vapor at inside temperature, BTU/lb,

HG3 = enthalpy of saturated water vapor at incoming temperature, BTU/lb,

PW1 = saturation pressure at incoming wet-bulb temperature, in Hg,

PW2 = saturation pressure at inside dry-bulb temperature, in Hg,

PW3 = saturation pressure at incoming dry-bulb temperature, in Hg,

QSUM = total heat transfer through the structural components of the confinement unit, BTU/hr,

SENS = total sensible heat production of the confined animals and other sources within the confinement unit, BTU/hr,

RH = relative humidity at ventilation rate required to remove moisture, percent, RH1 = relative humidity at ventilation rate required to remove heat load, percent,

RH2 = incoming relative humidity, percent,

SUMQ = total sensible heat load within confinement unit, BTU/hr,

SUP = heat load necessary to ensure a ventilation rate required to remove moisture, BTU/hr,

TW1 = incoming wet-bulb temperature, °F,

U = degree of saturation,

V1 = specific volume of incoming air, ft^3/lb d.a.,

WM = total moisture production within the confinement unit, lb moisture/lb d.a.,

WS = absolute humidity at saturation (inside conditions), lb moisture/lb d.a.,

WSS = absolute humidity at saturation (outside conditions), lb moisture/lb d.a.,

W1 = absolute humidity of incoming air, lb moisture/lb d.a.

C8. PH2O and PICE Variable Names and Units.

A = absolute temperature, °K,

C = temperature, °C,

I = time, hr,

P = saturation vapor pressure, atmospheres,

PP = saturation vapor pressure, in Hg,

T = temperature, °F,

TT = 8 = $\frac{273.16}{^{\circ}K}$

APPENDIX D: INPUT DATA FORMAT

Group	Variable	Variable Name	Number of Cards	Format
I	1. simulation period	TNT	1	1X,F3.0,F3.0, 6F3.2,F4.1
	2. attic thickness	AVH		
	3. emissivity factor for outer wall surface	EW		
	4. absorptivity factor for outer wall surface	AW		
	5. absorptivity factor for roof surface	AR		
	6. emissivity factor for roof surface	ER		
	7. heat transfer coefficient for windows installed	UA		
	8. shading coefficient	SC		
	9. relative humidity at ventilation rate required to remove moisture	RH		
II	supplemental heat output of heater	HEATR	3,5,7,9[a]	11F7.0
III	hog weight	HOGWT	1	10F3.0
IV	hog number	HOGS	1	10F3.0
V	1. management factor for moisture production	MGMT	1	2F4.2
	2. management factor for sensible heat production	MGMTS		
VI	barometric pressure	B	2,3,5,6[a]	16F5.2
VII[b]	1. total number of animals	AN	1	17F4.0
	2. area of east wall	AEWA		
	3. area of north wall	ATWA		
	4. area of south wall	ASWA		
	5. area of west wall	AWWA		
	6. area of east doors	AEDO		
	7. area of north doors	ATDO		
	8. area of south doors	ASDO		
	9. area of west doors	AWDO		
	10. area of east windows	AEWI		
	11. area of north windows	ATWI		
	12. area of south windows	ASWI		
	13. area of west windows	AWWI		
	14. perimeter of unit	AFLO		
	15. area of east roof slope	ARO1		
	16. area of west roof slope	ARO2		
	17. area of horizontal roof	ARO3		

APPENDIX D: CONTINUED

Group	Variable	Variable Name	Number of Cards	Format
VIII	ventilation rate	VENT	3,5,7,9[a]	11F7.0
IX	allowable error in ventilation rate calculation	ERROR	1	F5.2
X	1. outside air film conductance coefficient	COEF1	1	6F4.2
	2. inside air film conductance coefficient for horizontal roof	COEFI(1)		
	3. inside air film conductance coefficient for walls	COEFI(2)		
	4. inside air film conductance coefficient for pitched roof	COEFI(3)		
	5. emissivity factor for upper attic surface	EE1		
	6. emissivity factor for lower attic surface	EE2		
XI	ingoing temperature indicator	IATTIC	1	I3
XII	attic dry-bulb temperature	ATTD	2,4,6,8[a,c]	12F6.1
XIII	attic wet-bulb temperature	ATTW	2,4,6,8[a,c]	12F6.1
XIV	polynomial coefficients for use in calculation of absorption factor of the inner window pane	AIN	1	6F10.5
XV	polynomial coefficients for use in calculation of absorption factor of the outer window pane	AOUT	1	6F10.5
XVI	polynomial coefficients for use in calculation of the transmission factor of the window	T	1	6F10.5
XVII	1. latitude of location	PLAT	1	2F7.2,2F3.0, 3A4
	2. longitude of location	PLONG		
	3. time zone number	TZN		
	4. daylight saving time indicator	DST		
	5. location	LO,CA,TX		

APPENDIX D: CONTINUED

Group	Variable	Variable Name	Number of Cards	Format
XVIII[b,d]	1. surface tilt angle	WALLT	7	2F7.2,I3, 2X,3A4
	2. surface azimuth angle	WALLA		
	3. counter	ISTOP		
	4. surface indicator	EA,EB,EC		
XIX	1. day of the year	D	1	F5.0,3A4
	2. date	X,U,Z		
XX[e]	1. clearance number	CN	1	F4.1,I1, F5.2,4F4.2
	2. cloud type	CT		
	3. ground reflectivity	R		
	4. parameter a/ho	ARO		
	5. coefficient of heat transfer by radiation and convection at the outer surface	HO		
	6. inward flowing fraction of the radiation absorbed by the inner window pane	NII		
	7. inward flowing fraction of the radiation absorbed by the outer window pane	NID		
XXI	total cloud amount	TC	1	24F2.0
XXII	outside dry-bulb temperature	OT	2	12F5.1
XXIII	outside wet-bulb temperature	OW	2	12F5.1
XXIV[j]			variable	
XXV	1. sampling time interval	DT	1	F10.3,I2, F2.0
	2. surface indicator	ICOMP		
	3. direction of heat flow through the attic space	ZZZ		
XXVI	title	TEXT1	2	80A1
XXVII	1. layer thickness	XL	variable[f]	5F10.4, 30A1
	2. thermal conductivity	XK		
	3. density	D		
	4. specific heat	SH		
	5. resistance	RES		
	6. description of layer	TEXT		
XXVIII[g]			1	

APPENDIX D: CONTINUED

Group	Variable	Variable Name	Number of Cards	Format
XXIX	1. boundary conditions 2. number of frequencies	ICASE NW	1	I1,I1
XXX	frequency periods	W	1[c]	8F10.4
XXXI[h]			variable	
XXXII[i]			1	

a. Each number represents the number of cards required for 1,2,3 and 4 days of simulation respectively.

b. The orientations may be altered in Group VII but must correspond with the orientation as specified in Group XVIII. (e.g. where the east surface is altered to some other orientation in Group VII, the card representing the east slope, i.e., card number 3 of Group XVIII, must be altered to represent this new orientation).

c Optional

d. There must be seven surfaces whose orientation is specified. These must be in the following order: south wall, west wall, east wall, north wall, west roof slope, east roof slope and horizontal roof. Where there are less than seven orientations, insert 'dummy' data. Note: The order may be altered to suit the specific situation, but the changes must be made simultaneously to Group VII.

e. Data must correspond to the data specified in Group XIX.

f. One card is necessary for each layer of the component, to a maximum of 20 layers per component.

g. A blank card must be inserted to terminate the input of Group XXVII.

APPENDIX D: CONTINUED

h. Group XXV to Group XXX must be repeated for each of the four surfaces, i.e., walls, horizontal roof, pitched roof, and doors. When either the horizontal roof or pitched roof is used, insert 'dummy' data for this section not used.

i. A blank card must be inserted to terminate the reading of input.

j. Group XIX to Group XXIII must be repeated for each day of the simulation period.

APPENDIX E: INPUT DATA SPECIFICATION.

The following input variables are defined and specified as in Appendix D. The order in which they are specified is also as per Appendix D.

I* TNT = 0 for one day,
= 1 for two days,
= 2 for three days, and
= 3 for four days;

AVH = one-half the gable height (inches);

$$\left.\begin{array}{l}\mathrm{EW}\\ \mathrm{AW}\\ \mathrm{AR}\\ \mathrm{ER}\\ \mathrm{UA}\\ \mathrm{SC}\end{array}\right\} = \text{constants;}$$

RH = percent relative humidity;

II HEATR = British Thermal Units per hour for each hour of the simulation period;

III HOGWT = the weight (pounds) of a maximum of ten groups of hogs;

IV HOGS = the number of hogs in each of the weight groups specified in HOGWT;

V MGMT = constant,
e.g. 1.20 represents an increase of 20% while
0.80 represents a decrease of 20% over the
data of Bond et al (26);

MGMTS = constant, e.g., as per MGMT;

* Group as per Appendix D.

APPENDIX E: CONTINUED

VI B = inches of mercury for each hour of the simulation period;

VII AN = constant, i.e., total number of hogs confined;

AEWA
ATWA
ASWA
AWWA
AEDO
ATDO
ASDO
AWDO = areas of the component in square feet;
AEWI
ATWI
ASWI
AWWI
AR01
AR02
AR03

AFLO = perimeter of unit in feet;

VIII VENT = cubic feet per minute for each hour of the simulation period;

IX ERROR = constant, e.g., 0.03 for ± 3% error;

X COEF1
COEFI(1) = British Thermal Units/(foot)^2(hour)(degree Fahrenheit);
COEFI(2)
COEFI(3)

EE1 = constants;
EE2

APPENDIX E: CONTINUED

XI IATTIC = 0 for outside temperature, and
= 1 for attic temperature;

XII ATTD = degrees Fahrenheit;

XIII ATTW = degrees Fahrenheit;

XIV AIN
XV AOUT
XVI T
} constants; these are designed for double-glazed windows. If only single-glazed windows exist, the values are entered for calculation of the absorption factor of the inner window pane and the coefficients for the outer pane are set to zero (blank card);

XVII PLAT = degrees, + North, and
- South;

PLONG = degrees, + West, and
- East;

TZN = constant, hours behind Greenwich mean time;

DST = 0 for standard time, and
= 1 for daylight saving time;

LO
CA
TX
} = any symbols up to a maximum of twelve characters;

XVIII WALLT = degrees from horizontal;

WALLA = degrees from South, + West of South, and
- East of South;

ISTOP = numbers one to seven, one for each surface, to ensure that seven cards are inserted;

EA
EB
EC
} = any combination of twelve symbols indicating the surface in consideration;

APPENDIX E: CONTINUED

XIX D * day of the year, 1 to 366;

$\left.\begin{array}{l}X\\U\\Z\end{array}\right\}$ = date, any combination of twelve symbols indicating the date;

XX CT = 0 for cirrus or cirrostratus,

= 1 for stratus, and

= 2 for other type;

CN = constant;

R = constant;

ARO = a/ho, where a = absorptance of the surface for solar radiation, and

ho = coefficient of heat transfer by radiation and convection at the outer surface, BTU/(hr)(ft)^2(^{o}F);

HO = British Thermal Units/(hour)(square foot)(degree Fahrenheit)

$\left.\begin{array}{l}NII\\NIO\end{array}\right\}$ = constants;

XXI TC = constant value on the scale of 0 to 10 for each hour of the simulation period, 0 representing no cloud cover and 10 representing total cloud cover;

XXII OT = degrees Fahrenheit;

XXIII OW = degrees Fahrenheit;

XXV DT = hours;

ICOMP = 1 for walls,

= 2 for pitched roof,

= 3 for horizontal roof, and

= 4 for doors;

APPENDIX E: CONTINUED

ZZZ = 1 for upwards, and

= 2 for downwards;

XXVI TEXT1 = any title;

XXVII XL = feet;

XK = British Thermal Units/(hour)(degree Fahrenheit)(foot)^2;

D = pounds/cubic foot;

SH = British Thermal Units/(pound)(degree Fahrenheit);

RES = resistance of the radiation path whenever applicable or thermal resistance of layer when there is negligible heat storage;

TEXT = any characters representing the description of the layer;

XXIX ICASE = boundary conditions of the first kind (temperature, given for both surfaces)

A) ramp input, ICASE = 1,

B) frequency response, ICASE = 2, and

of the second kind (flux given for both surfaces)

A) step input, ICASE = 3,

B) ramp input, ICASE = 4, and

C) frequency response, ICASE = 5;

NW = number of frequencies only when frequency response is involved; and

W = frequency periods only when frequency response is involved.

APPENDIX F: TIME REPRESENTATION

Hour	Actual Time	Hour	Actual Time
1	1:00 AM, September 10	25	1:00 AM, September 11
2	2:00 AM, September 10	26	2:00 AM, September 11
3	3:00 AM, September 10	27	3:00 AM, September 11
4	4:00 AM, September 10	28	4:00 AM, September 11
5	5:00 AM, September 10	29	5:00 AM, September 11
6	6:00 AM, September 10	30	6:00 AM, September 11
7	7:00 AM, September 10	31	7:00 AM, September 11
8	8:00 AM, September 10	32	8:00 AM, September 11
9	9:00 AM, September 10	33	9:00 AM, September 11
10	10:00 AM, September 10	34	10:00 AM, September 11
11	11:00 AM, September 10	35	11:00 AM, Septemger 11
12	NOON, September 10	36	NOON, September 11
13	1:00 PM, September 10	37	1:00 PM, September 11
14	2:00 PM, September 10	38	2:00 PM, September 11
15	3:00 PM, September 10	39	3:00 PM, September 11
16	4:00 PM, September 10	40	4:00 PM, September 11
17	5:00 PM, September 10	41	5:00 PM, Septamber 11
18	6:00 PM, September 10	42	6:00 PM, September 11
19	7:00 PM, September 10	43	7:00 PM, September 11
20	8:00 PM, September 10	44	8:00 PM, September 11
21	9:00 PM, September 10	45	9:00 PM, September 11
22	10:00 PM, September 10	46	10:00 PM, September 11
23	11:00 PM, September 10	47	11:00 PM, September 11
24	MIDNIGHT, September 10	48	MIDNIGHT, September 11

APPENDIX F: CONTINUED

Hour	Actual Time
49	1:00 AM, September 12
50	2:00 AM, September 12
51	3:00 AM, September 12
52	4:00 AM, September 12
53	5:00 AM, September 12
54	6:00 AM, September 12
55	7:00 AM, September 12
56	8:00 AM, September 12
57	9:00 AM, September 12
58	10:00 AM, September 12
59	11:00 AM, September 12
60	NOON, September 12
61	1:00 PM, September 12
62	2:00 PM, September 12
63	3:00 PM, September 12
64	4:00 PM, September 12
65	5:00 PM, September 12
66	6:00 PM, September 12
67	7:00 PM, September 12
68	8:00 PM, September 12
69	9:00 PM, September 12
70	10:00 PM, September 12
71	11:00 PM, September 12
72	MIDNIGHT, September 12

APPENDIX G: DATA.

The tables in this appendix are the experimentally recorded data (observed) as well as the data predicted by the model.

TABLE G1: OBSERVED DRY-BULB TEMPERATURES, °F.

Time	Inside			Outside	Attic
	Parallel Circuit Average	12" fan	16" fan		
20	75.8	75.6	74.0	64.2	73.1
21	73.5	73.5	70.8	59.6	67.4
22	72.0	72.0	69.4	56.5	63.3
23	70.5	70.3	67.7	52.9	59.5
24	69.4	69.1	66.4	51.3	57.0
25	68.2	68.1	73.2	52.1	55.7
26	68.0	67.9	76.4	53.6	56.1
27	68.0	67.5	75.5	53.0	56.3
28	67.4	67.3	77.1	51.7	55.6
29	66.7	66.8	69.4	51.8	55.1
30	66.4	66.4	67.7	51.5	55.0
31	66.1	66.1	69.8	49.6	53.5
32	66.8	66.9	64.2	52.2	53.0
33	69.4	68.6	71.8	55.9	56.6
34	69.2	69.2	65.4	59.6	60.4
35	71.1	71.1	67.9	62.3	66.4
36	73.2	73.2	70.8	66.4	71.3
37	76.2	75.6	74.6	69.1	77.8
38	78.5	77.5	76.8	72.4	82.5
39	80.4	79.2	78.7	75.6	85.8
40	81.3	80.1	79.9	76.1	86.4
41	82.1	80.6	80.5	77.2	86.2
42	80.8	79.9	80.1	74.0	82.8
43	78.6	78.5	77.0	70.3	78.4
44	77.6	77.2	77.2	67.8	73.8
45	75.0	75.0	72.8	59.4	68.6
46	73.0	73.0	70.7	59.5	64.5
47	71.8	72.1	69.4	57.5	63.0
48	68.7	69.8	67.5	52.6	60.2
49	68.6	68.8	66.3	51.8	57.7

Cont'd.

TABLE G1: Continued

Time	Inside			Outside	Attic
	Parallel Circuit Average	12" fan	16" fan		
50	67.3	67.5	65.6	51.7	56.4
51	66.3	66.9	65.0	50.4	55.8
52	65.6	66.1	63.8	49.9	54.6
53	65.4	65.6	62.7	50.3	54.5
54	65.4	65.7	62.2	49.0	53.5
55	65.4	65.4	64.0	48.7	52.5
56	66.3	66.2	63.3	49.1	51.5
57	68.0	67.5	71.1	50.4	53.2
58	67.6	67.5	69.7	50.6	55.1
59	66.4	66.5	66.6	48.0	55.0
60	66.4	66.4	64.8	44.3	54.1
61	66.8	66.5	64.0	44.4	53.1
62	67.2	66.6	64.8	43.3	52.9
63	65.5	65.3	64.0	42.4	50.9
64	65.3	65.0	62.3	39.0	49.5
65	64.0	64.0	61.7	39.0	47.7
66	62.2	62.4	59.7	37.3	46.1
67	60.5	60.7	57.8	35.4	44.6
68	62.5	62.5	57.5	33.3	42.6
69	60.4	60.6	57.4	33.7	42.8

TABLE G2: OBSERVED AND PREDICTED RELATIVE HUMIDITIES, %.

Time	Outside	Attic	Inside		
			Observed	Model A	Model B
20	68.7	52.2	62.9	63.1	62.8
21	71.8	60.4	65.7	65.1	65.0
22	77.7	66.9	68.6	70.0	69.9
23	82.6	69.8	71.2	73.0	73.0
24	80.9	71.6	70.8	72.3	72.3
25	78.3	72.1	71.6	71.8	71.8
26	76.0	70.7	71.1	71.1	71.1
27	78.1	70.8	71.5	71.9	71.9
28	79.3	72.0	71.7	72.0	72.0
29	80.5	72.3	71.0	73.5	73.5
30	78.1	72.3	70.9	71.4	71.4
31	80.4	72.7	71.2	72.1	72.1
32	77.8	71.3	68.0	70.9	70.7
33	72.2	69.4	69.2	66.4	65.8
34	66.5	65.9	67.0	62.0	60.8
35	59.7	61.2	65.8	56.4	55.1
36	57.0	60.2	65.6	55.6	53.7
37	56.3	56.3	62.4	55.6	53.7
38	53.0	53.5	61.7	53.8	51.9
39	50.0	51.8	60.4	52.6	50.8
40	48.0	51.5	64.5	50.3	48.6
41	46.8	50.5	60.5	49.8	48.4
42	52.2	52.7	62.0	52.9	51.7
43	58.6	57.0	65.6	57.2	56.4
44	61.2	63.4	68.5	59.4	59.1
45	73.9	63.3	69.4	65.6	65.4
46	70.9	65.0	69.0	66.1	66.0
47	75.6	66.5	70.6	69.5	69.4
48	82.7	67.8	71.0	72.5	72.5
49	81.8	69.0	69.3	73.2	73.2
50	82.4	69.9	70.0	74.4	74.4

Cont'd.

TABLE G2: Continued

Time	Outside	Attic	Inside		
			Observed	Model A	Model B
51	83.2	69.1	70.5	74.4	74.4
52	83.0	70.6	70.2	74.5	74.5
53	83.1	70.5	71.0	75.2	75.2
54	80.8	70.0	69.3	72.6	72.6
55	78.2	71.7	71.1	70.8	70.8
56	75.3	70.6	67.1	67.8	67.6
57	76.5	69.9	69.6	68.7	68.2
58	75.4	67.4	70.7	67.1	66.2
59	73.6	67.6	70.2	63.8	62.6
60	69.5	67.1	69.8	59.8	58.4
61	74.9	68.7	70.0	65.1	63.4
62	77.1	68.0	70.1	66.5	64.8
63	78.1	66.2	71.2	67.2	65.4
64	72.5	66.4	69.4	62.2	60.6
65	73.2	65.2	68.3	64.1	62.2
66	71.1	66.0	70.7	63.4	62.2
67	67.3	66.2	72.3	60.3	59.6
68	62.8	71.7	64.8	51.6	51.3
69	66.9	67.6	70.8	54.2	54.1

TABLE G3: OBSERVED AND PREDICTED INSIDE DRY-BULB TEMPERATURES, °F.

Time	Observed	Model A	Model B	
			Outside as incoming temperature	Attic as incoming temperature
20	75.8	70.9	71.1	78.0
21	73.5	66.6	66.7	72.9
22	72.0	63.7	63.7	69.1
23	70.5	60.5	60.5	65.6
24	69.4	58.7	58.7	63.3
25	68.2	58.8	58.8	62.0
26	68.0	59.8	59.8	62.0
27	68.0	59.6	59.6	62.2
28	67.4	58.7	58.7	61.7
29	66.7	58.6	58.6	61.2
30	66.4	58.4	58.4	61.1
31	66.1	57.0	57.0	60.0
32	66.8	59.2	59.3	60.3
33	69.4	62.7	63.1	63.7
34	69.2	66.1	66.7	67.4
35	71.1	68.8	70.2	72.4
36	73.2	72.1	73.2	76.6
37	76.2	74.4	75.6	81.5
38	78.5	77.1	78.3	85.3
39	80.4	79.6	80.7	87.8
40	81.3	80.4	81.4	88.7
41	82.1	81.1	82.0	88.5
42	80.8	78.9	79.6	86.0
43	78.6	75.8	76.2	82.4
44	77.6	73.3	73.5	78.4
45	75.0	67.0	67.1	73.6
46	73.0	65.8	65.8	70.1
47	71.8	64.1	64.1	68.3
48	68.7	60.4	60.4	65.9
49	68.6	59.1	59.1	63.8

Cont'd.

TABLE G3: Continued

Time	Observed	Model A	Model B: Outside as incoming temperature	Model B: Attic as incoming temperature
50	67.3	58.7	58.7	62.6
51	66.3	57.7	57.7	61.9
52	65.6	57.2	57.2	60.9
53	65.4	57.3	57.3	60.6
54	65.4	56.4	56.4	59.9
55	65.4	56.0	56.0	59.1
56	66.3	56.8	56.9	59.0
57	68.0	58.0	58.2	60.4
58	67.6	58.5	58.9	62.5
59	66.4	56.9	57.5	62.6
60	66.4	54.1	54.8	62.0
61	66.8	53.5	54.2	61.1
62	67.2	52.5	53.3	60.7
63	65.5	51.7	52.5	59.3
64	65.3	49.1	49.9	57.9
65	64.0	48.5	49.2	56.2
66	62.2	47.0	47.6	54.5
67	60.5	45.2	45.6	52.7
68	62.5	46.4	46.6	53.9
69	60.4	46.7	46.7	53.9

TABLE G4: OBSERVED AND PREDICTED NORTH WALL SURFACE TEMPERATURES, °F.

Time	Outside			Inside		
	Observed	Model A	Model B	Observed	Model A	Model B
20	60.8	65.0	65.2	71.9	71.7	71.9
21	56.0	60.2	60.2	69.9	67.2	67.3
22	53.4	57.0	57.0	68.4	64.0	64.0
23	51.3	53.4	53.4	66.6	60.7	60.8
24	50.4	51.6	51.6	65.2	58.7	58.7
25	51.3	52.2	52.2	64.1	58.4	58.4
26	52.8	53.6	53.6	63.8	59.2	59.2
27	52.3	53.2	53.2	63.8	59.2	59.2
28	50.8	51.9	51.9	63.4	58.4	58.4
29	51.3	51.9	51.9	62.6	58.4	58.4
30	50.8	51.7	51.7	62.4	58.0	58.0
31	48.8	49.9	49.9	61.9	56.8	56.8
32	50.9	52.6	53.5	60.7	58.4	58.5
33	55.5	57.0	59.5	63.2	61.6	62.0
34	60.2	61.4	65.1	63.3	65.0	65.7
35	63.3	64.7	69.5	65.2	67.9	69.3
36	66.9	69.1	74.6	67.2	71.1	72.5
37	69.9	72.1	78.0	69.6	73.7	75.2
38	72.5	75.3	81.0	71.9	76.4	77.9
39	75.4	77.7	82.2	74.2	78.9	80.3
40	74.6	78.7	83.5	75.7	80.0	81.3
41	74.4	78.9	82.0	76.6	80.8	81.9
42	71.4	75.5	77.6	76.4	79.1	80.0
43	67.6	71.2	72.1	75.2	76.2	76.7
44	65.8	68.2	68.3	73.7	73.6	73.8
45	56.6	60.3	60.3	71.7	67.8	68.0
46	58.8	59.7	59.7	69.6	65.8	65.8
47	57.7	57.8	57.8	68.2	64.1	64.1
48	52.0	53.2	53.2	65.2	60.7	60.7
49	51.0	52.1	52.1	62.9	59.0	59.0
50	51.9	51.9	51.9	61.3	58.4	58.4

Cont'd.

TABLE G4: Continued

Time	Outside			Inside		
	Observed	Model A	Model B	Observed	Model A	Model B
51	51.3	50.7	50.7	60.6	57.4	57.4
52	50.7	50.1	50.1	59.5	56.8	56.8
53	51.0	50.4	50.4	59.2	56.8	56.8
54	48.6	49.3	49.3	58.6	56.1	56.1
55	48.0	48.9	48.9	60.6	55.6	55.6
56	48.1	49.6	50.3	60.2	56.2	56.3
57	51.4	51.2	52.5	62.0	57.3	57.5
58	53.6	51.8	53.8	62.3	57.9	58.4
59	51.0	49.8	52.3	61.7	56.7	57.4
60	49.7	46.4	49.3	61.4	54.2	55.0
61	49.3	46.3	49.4	62.1	53.2	54.1
62	46.5	45.3	48.4	61.2	52.2	53.2
63	45.2	44.3	47.2	60.0	51.4	52.3
64	43.0	40.9	43.5	59.3	49.1	50.0
65	41.2	40.4	42.5	58.0	48.2	49.0
66	40.1	38.4	39.9	56.8	46.7	47.4
67	39.2	36.1	36.8	55.6	45.0	45.5
68	36.8	33.8	33.8	56.7	45.5	45.7
69	36.9	33.9	34.0	57.0	45.8	45.8

TABLE G5: OBSERVED AND PREDICTED WEST WALL SURFACE TEMEPRATURES, °F.

Time	Outside			Inside		
	Observed	Model A	Model B	Observed	Model A	Model B
20	71.4	65.6	66.7	77.2	71.9	72.6
21	60.9	60.3	60.3	73.2	67.2	67.5
22	56.7	57.0	57.0	70.1	64.0	64.0
23	53.6	53.4	53.4	67.5	60.7	60.8
24	51.7	51.6	51.6	65.6	58.7	58.7
25	52.2	52.2	52.2	64.2	58.4	58.4
26	53.5	53.6	53.6	63.8	59.2	59.2
27	53.5	53.2	53.2	64.0	59.2	59.2
28	52.5	51.9	51.9	63.5	58.4	58.4
29	52.7	51.9	51.9	63.0	58.4	58.4
30	52.1	51.7	51.7	62.9	58.0	58.0
31	50.4	49.9	49.9	62.4	56.8	56.8
32	52.2	52.6	53.4	62.1	58.4	58.5
33	56.9	57.0	59.5	63.7	61.6	62.0
34	60.7	61.4	65.1	64.7	65.0	65.7
35	64.0	64.7	69.5	66.8	67.9	69.3
36	67.1	69.1	74.6	69.0	71.1	72.5
37	71.1	72.2	78.2	71.9	73.7	75.2
38	76.4	77.4	87.0	74.6	76.4	78.1
39	87.0	82.5	95.7	77.1	79.1	81.0
40	92.9	88.0	109.9	79.7	80.5	82.7
41	100.8	87.9	107.8	82.3	81.4	83.6
42	84.5	84.1	102.3	81.5	79.7	81.7
43	62.4	75.6	84.6	78.8	76.6	77.9
44	67.8	68.5	69.3	76.3	73.7	74.3
45	58.1	60.3	60.4	73.7	67.9	68.1
46	58.9	59.7	59.7	70.7	65.8	65.9
47	58.5	57.8	57.8	69.6	64.1	64.1
48	53.4	53.2	53.2	67.8	60.7	60.7
49	52.1	52.1	52.1	66.4	59.0	59.0
50	52.5	51.9	51.9	65.4	58.4	58.4

Cont'd.

TABLE G5: Continued

Time	Outside			Inside		
	Observed	Model A	Model B	Observed	Model A	Model B
51	51.9	50.7	50.7	64.7	57.4	57.4
52	51.4	50.1	50.1	63.8	56.8	56.8
53	51.8	50.4	50.4	63.6	56.8	56.8
54	50.0	49.3	49.3	62.7	56.1	56.1
55	49.0	48.9	48.9	62.1	55.6	55.6
56	49.4	49.6	50.3	61.7	56.2	56.3
57	51.8	51.2	52.5	62.9	57.3	57.5
58	53.3	51.8	53.8	63.2	57.9	58.4
59	50.5	49.8	52.3	62.8	56.7	57.4
60	49.1	46.4	49.3	62.3	54.2	55.0
61	49.6	46.4	49.5	61.8	53.2	54.1
62	46.6	46.5	51.7	61.8	52.3	53.3
63	44.8	47.7	56.6	60.6	51.5	52.8
64	43.3	46.2	58.1	60.0	49.4	50.8
65	41.9	46.7	60.1	59.4	48.5	50.1
66	40.8	44.5	56.9	56.0	47.2	48.6
67	39.9	39.5	46.2	56.7	45.3	46.3
68	37.8	34.1	34.6	57.4	45.6	46.1
69	38.2	34.0	34.0	56.5	45.8	45.9

TABLE G6: OBSERVED AND PREDICTED SOUTH WALL SURFACE TEMPERATURES, °F.

Time	Outside			Inside		
	Observed	Model A	Model B	Observed	Model A	Model B
20	63.9	65.1	65.3	74.3	71.7	72.0
21	59.9	60.2	60.2	69.6	67.2	67.3
22	56.9	57.0	57.0	67.9	64.0	64.0
23	53.8	53.4	53.4	66.8	60.7	60.8
24	52.4	51.6	51.6	65.6	58.7	58.7
25	52.7	52.2	52.2	64.9	58.4	58.4
26	54.2	53.6	53.6	65.5	59.2	59.2
27	53.7	53.2	53.2	65.8	59.2	59.2
28	53.0	51.9	51.9	66.0	58.4	58.4
29	53.5	51.9	51.9	63.8	58.4	58.4
30	52.2	51.7	51.7	62.8	58.0	58.0
31	50.6	49.9	49.9	62.6	56.8	56.8
32	53.4	52.9	54.4	62.3	58.4	58.5
33	59.4	60.0	67.8	65.0	61.7	62.3
34	73.2	67.5	82.4	65.1	65.3	66.6
35	75.2	74.0	95.8	67.4	68.4	70.8
36	90.8	80.7	107.4	70.2	71.8	74.5
37	97.6	84.9	114.3	73.6	74.5	77.5
38	100.0	87.8	116.6	76.3	77.2	80,3
39	98.3	87.0	108.6	78.2	79.6	82.4
40	93.0	88.0	110.2	79.4	80.7	83.2
41	91.5	84.2	97.4	80.2	81.3	83.3
42	79.0	78.2	85.3	79.8	79.4	80.8
43	71.4	71.6	73.3	76.4	76.3	77.0
44	68.4	68.2	68.4	73.4	73.6	73.9
45	61.4	60.3	60.3	71.5	67.9	68.0
46	60.6	59.7	59.7	68.6	65.8	65.8
47	58.9	57.8	57.8	68.1	64.1	64.1
48	54.8	53.2	53.2	66.5	60.7	60.7
49	53.4	52.1	52.1	65.2	59.0	59.0
50	53.7	51.9	51.9	64.8	58.4	58.4

Cont'd.

TABLE G6: Continued

Time	Outside			Inside		
	Observed	Model A	Model B	Observed	Model A	Model B
51	53.1	50.7	50.7	64.6	57.4	57.4
52	52.5	50.1	50.1	63.3	56.8	56.8
53	52.6	50.4	50.4	62.3	56.8	56.8
54	50.4	49.3	49.3	61.6	56.1	56.1
55	49.7	48.9	48.9	61.9	55.6	55.6
56	50.0	49.9	51.1	61.9	56.2	56.3
57	53.3	52.8	57.0	63.9	57.3	57.7
58	54.8	55.2	63.4	63.7	58.1	58.8
59	51.9	54.8	66.5	62.6	57.0	58.2
60	50.6	52.7	67.0	62.4	54.5	56.0
61	52.2	53.3	68.9	62.8	53.7	55.3
62	49.8	52.4	68.1	63.3	52.7	54.5
63	47.7	50.8	65.3	61.9	51.8	53.6
64	45.9	46.3	58.4	61.5	49.5	51.1
65	44.1	44.1	52.9	60.0	48.5	49.8
66	42.4	40.4	45.2	58.9	46.9	48.0
67	40.9	36.5	37.7	57.8	45.1	45.7
68	38.8	33.8	33.9	57.5	45.5	45.8
69	38.7	33.9	34.0	57.4	45.8	45.8

TABLE G7: OBSERVED AND PREDICTED EAST WALL SURFACE TEMPERATURES, °F.

Time	Outside			Inside		
	Observed	Model A	Model B	Observed	Model A	Model B
20	59.5	65.0	65.1	74.7	71.7	71.9
21	57.8	60.2	60.2	72.0	67.2	67.3
22	54.7	57.0	57.0	70.0	64.0	64.0
23	51.5	53.4	53.4	67.9	60.7	60.8
24	50.8	51.6	51.6	66.2	58.7	58.7
25	51.8	52.2	52.2	65.0	58.4	58.4
26	53.4	53.6	53.6	65.0	59.2	59.2
27	53.4	53.2	53.2	64.9	59.2	59.2
28	52.4	51.9	51.9	64.4	58.4	58.4
29	52.7	51.9	51.9	64.0	58.4	58.4
30	52.1	51.7	51.7	64.0	58.0	58.0
31	50.4	49.9	49.9	63.3	56.8	56.8
32	63.2	57.8	68.0	63.9	58.6	59.0
33	65.3	67.8	89.7	66.3	62.1	63.5
34	82.0	72.9	97.5	67.9	65.7	67.8
35	75.4	74.8	97.8	70.2	68.6	71.3
36	82.1	75.9	94.0	72.2	71.7	74.1
37	74.1	74.9	85.8	74.7	74.0	76.1
38	72.4	75.6	81.9	76.6	76.5	78.2
39	74.2	77.8	82.2	78.5	78.9	80.4
40	74.4	78.7	83.5	79.5	80.0	81.3
41	74.1	78.9	82.0	79.9	80.8	81.9
42	71.5	75.5	77.6	79.1	79.1	80.0
43	68.6	71.2	72.0	77.6	76.2	76.7
44	66.5	68.2	68.3	76.0	73.5	73.8
45	60.4	60.3	60.3	73.8	67.9	68.0
46	59.9	59.7	59.7	71.3	65.8	65.8
47	58.5	57.8	57.8	70.1	64.1	64.1
48	54.3	53.2	53.2	68.2	60.7	60.7
49	52.9	52.1	52.1	66.7	59.0	59.0
50	52.9	51.9	51.9	65.7	58.4	58.4

Cont'd.

TABLE G7: Continued

Time	Outside			Inside		
	Observed	Model A	Model B	Observed	Model A	Model B
51	52.3	50.7	50.7	64.9	57.4	57.4
52	51.4	50.1	50.1	64.1	56.8	56.8
53	51.8	50.4	50.4	63.8	56.8	56.8
54	50.0	49.3	49.3	63.0	56.1	56.1
55	49.1	48.9	48.9	62.8	55.6	55.6
56	50.1	53.8	62.1	62.8	56.3	56.7
57	56.4	57.0	68.9	64.1	57.6	58.4
58	57.2	58.1	71.5	64.7	58.3	59.5
59	51.9	55.2	67.5	64.0	57.1	58.5
60	50.6	50.1	59.6	63.6	54.5	55.8
61	51.5	47.8	53.5	63.4	53.4	54.5
62	49.6	45.5	48.9	63.4	52.3	53.3
63	47.2	44.3	47.3	62.1	51.4	52.4
64	45.2	41.0	43.5	61.3	49.1	50.0
65	43.2	40.4	42.5	60.2	48.2	49.0
66	41.5	38.4	39.9	59.0	46.7	47.4
67	40.6	36.1	36.7	57.9	45.0	45.5
68	38.6	33.8	33.8	58.0	45.5	45.7
69	38.6	33.9	34.0	57.8	45.8	45.8

TABLE G8: OBSERVED AND PREDICTED ROOF AND CEILING SURFACE TEMPERATURES, °F.

Time	Outside						Ceiling		
	East Slope			West Slope					
	Observed	Model A	Model B	Observed	Model A	Model B	Observed	Model A	Model B
20	59.7	65.4	65.1	66.4	66.2	66.6	75.5	71.8	72.1
21	55.7	60.4	60.4	56.8	60.5	60.6	73.5	67.2	67.3
22	52.5	57.1	57.1	52.3	57.1	57.1	72.1	64.0	64.0
23	49.7	53.6	53.6	48.9	53.6	53.6	70.6	60.8	60.8
24	48.6	51.7	51.7	47.4	51.7	51.7	69.4	58.7	58.7
25	49.6	52.2	52.2	48.8	52.2	52.2	68.4	58.4	58.4
26	51.8	53.5	53.5	51.1	53.5	53.5	68.0	59.2	59.2
27	51.7	53.2	53.2	51.0	53.2	53.2	67.8	59.2	59.2
28	50.7	52.0	52.0	50.1	52.0	52.0	67.4	58.5	58.5
29	51.2	51.9	51.9	50.7	51.9	51.9	66.6	58.2	58.2
30	50.3	51.7	51.7	49.3	51.7	51.7	66.2	58.0	58.0
31	48.2	50.0	50.0	47.4	50.0	50.0	65.9	56.8	56.8
32	55.5	57.5	60.8	49.2	53.0	52.2	65.1	58.5	58.7
33	62.3	70.3	80.5	54.7	57.7	56.7	67.7	61.9	62.5
34	82.6	79.9	95.5	66.8	65.0	67.4	67.4	65.6	66.5
35	84.6	86.6	105.0	73.4	73.4	80.1	69.3	68.7	70.5
36	99.8	91.9	111.0	84.8	82.8	93.9	71.2	72.2	74.1
37	104.0	93.8	112.1	95.8	90.2	105.3	73.4	74.8	76.9
38	102.2	93.7	110.4	101.3	95.8	114.3	75.7	77.6	79.7
39	98.7	89.6	101.5	105.2	95.6	112.9	77.9	80.0	82.0
40	91.0	88.3	96.3	101.3	100.1	118.9	79.1	81.0	82.8
41	86.1	82.8	86.9	103.5	94.7	109.4	79.9	81.6	83.1
42	76.2	76.7	77.8	87.0	87.4	98.1	79.3	79.6	80.8
43	70.0	71.9	72.2	73.0	76.4	80.8	78.2	76.5	77.1
44	66.6	68.4	68.4	67.2	68.9	69.4	76.7	73.7	74.0
45	62.1	60.6	60.6	60.2	60.7	60.7	75.3	67.9	68.0
46	60.0	59.8	59.8	58.7	59.8	59.8	72.9	65.8	65.9
47	58.1	57.9	57.9	57.4	57.9	57.9	71.7	64.1	64.1

Cont'd.

TABLE G8: Continued

Time	Outside						Ceiling		
	East Slope			West Slope					
	Observed	Model A	Model B	Observed	Model A	Model B	Observed	Model A	Model B
48	54.8	53.4	53.4	55.3	53.4	53.4	69.2	60.7	60.7
49	53.0	52.1	52.1	53.8	52.1	52.1	68.6	59.0	59.0
50	52.2	51.9	51.9	52.5	51.9	51.9	67.7	58.4	58.4
51	51.6	50.7	50.7	51.7	50.7	50.7	66.8	57.5	57.5
52	50.7	50.1	50.1	50.8	50.1	50.1	66.2	56.9	56.9
53	50.9	50.4	50.4	51.3	50.4	50.4	65.7	56.9	56.9
54	48.2	49.3	49.3	48.4	49.3	49.3	65.0	56.1	56.1
55	47.9	48.9	48.9	48.0	48.9	48.9	65.4	55.7	55.7
56	48.0	53.6	56.8	47.5	50.0	49.9	65.2	56.3	56.4
57	56.0	58.4	65.4	51.7	51.6	52.6	67.0	57.5	57.9
58	60.2	62.0	71.9	54.3	53.8	56.5	66.7	58.3	58.9
59	52.3	61.7	73.3	51.1	54.5	59.9	66.0	57.2	58.1
60	51.8	58.9	71.2	50.2	54.0	62.0	66.0	54.7	55.9
61	53.8	58.1	70.0	51.9	56.1	66.2	65.9	53.9	55.1
62	51.7	55.7	66.2	50.0	56.9	68.4	66.2	52.9	54.3
63	48.7	52.5	61.0	47.1	56.7	68.9	65.0	52.1	53.5
64	45.9	46.5	52.6	44.7	53.3	65.2	64.6	49.7	51.0
65	44.2	43.0	46.4	42.9	51.3	61.8	63.7	48.7	49.8
66	41.7	39.3	40.7	40.9	46.7	54.6	62.1	47.1	48.1
67	39.7	36.6	37.2	39.8	40.0	43.6	60.5	45.2	45.9
68	36.7	33.9	34.0	36.8	34.3	34.8	61.2	45.7	46.0
69	37.2	34.0	34.0	37.5	34.0	34.1	60.2	45.8	45.9

TABLE G9: OBSERVED AND PREDICTED INSIDE AIR DRY-BULB TEMPERATURES, °F.

Time	Observed	MGMT = 0.80 MGMTS			MGMT = 1.00 MGMTS			MGMT = 1.20 MGMTS		
		=0.80	=1.00	=1.20	=0.80	=1.00	=1.20	=0.80	=1.00	=1.20
20	75.8	71.1	72.2	73.1	70.3	71.1	72.1	69.5	70.2	70.8
21	73.5	66.5	67.9	68.7	65.7	66.7	67.9	65.0	65.8	66.6
22	72.0	63.3	64.6	65.5	62.6	63.7	64.8	61.9	62.8	63.7
23	70.5	60.0	61.4	62.6	59.3	60.5	61.7	58.7	59.7	60.7
24	69.4	58.2	59.5	60.9	57.5	58.7	59.9	56.9	58.0	59.0
25	68.2	58.3	59.6	61.0	57.6	58.8	60.0	57.0	58.1	59.1
26	68.0	59.3	60.6	62.0	58.6	59.8	61.0	58.0	59.1	60.1
27	68.0	59.1	60.4	61.7	58.4	59.6	60.8	57.8	58.8	59.8
28	67.4	58.1	59.5	60.8	57.5	58.7	59.9	56.8	57.9	59.0
29	66.7	58.0	59.4	60.7	57.4	58.6	59.8	56.7	57.8	58.9
30	66.4	57.8	59.2	60.5	57.1	58.4	59.6	56.5	57.6	58.7
31	66.1	56.4	57.8	59.2	55.7	57.0	58.3	55.1	56.3	57.4
32	66.8	58.7	60.1	61.4	58.0	59.3	60.5	57.4	58.5	59.5
33	69.4	62.6	63.9	65.0	61.9	63.1	64.2	61.2	62.2	63.2
34	69.2	66.4	67.9	68.7	65.7	66.7	67.9	65.0	65.9	66.7
35	71.1	69.5	70.7	71.7	68.8	70.2	70.6	68.0	68.8	70.1
36	73.2	73.1	74.4	75.1	72.3	73.2	74.3	71.5	72.2	72.9
37	76.2	75.7	77.0	77.5	74.8	75.6	77.0	74.0	74.5	75.1
38	78.5	78.6	79.5	80.2	77.6	78.3	79.0	76.8	77.2	77.6
39	80.4	81.1	81.9	82.6	80.2	80.7	81.2	79.2	79.5	79.8
40	81.3	82.0	82.7	83.4	81.0	81.4	81.9	80.0	80.3	80.5
41	82.1	82.6	83.3	84.0	81.6	82.0	82.4	80.5	80.8	81.0
42	80.8	80.1	80.8	81.6	79.1	79.6	80.1	78.1	78.5	78.8
43	78.6	76.5	77.4	78.2	75.6	76.2	76.9	74.7	75.2	75.6
44	77.6	73.6	74.6	75.7	72.8	73.5	74.3	71.9	72.5	73.0
45	75.0	66.9	68.0	69.1	66.1	67.1	68.0	65.4	66.2	66.9
46	73.0	65.5	66.7	68.0	64.9	65.8	66.8	64.2	65.0	65.7
47	71.8	63.8	65.0	66.0	63.0	64.1	65.0	62.3	63.3	64.1
48	68.7	59.9	61.3	62.5	59.2	60.4	61.5	58.6	59.6	60.6
49	68.6	58.5	59.9	61.3	57.9	59.1	60.3	57.3	58.3	59.4

Cont'd.

TABLE G9: Continued

Time	Observed	MGMT = 0.80			MGMT = 1.00			MGMT = 1.20		
		MGMST			MGMST			MGMST		
		=0.80	=1.00	=1.20	=0.80	=1.00	=1.20	=0.80	=1.00	=1.20
50	67.3	58.1	59.5	60.9	57.5	58.7	59.9	56.8	57.9	59.0
51	66.3	57.0	58.5	59.9	56.4	57.7	58.9	55.8	56.9	58.0
52	65.6	56.5	57.9	59.3	55.9	57.2	58.4	55.2	56.4	57.5
53	65.4	56.6	58.1	59.5	56.0	57.3	58.5	55.4	56.5	57.6
54	65.4	55.7	57.2	58.6	55.1	56.4	57.7	54.5	55.7	56.8
55	65.4	55.3	56.8	58.2	54.7	56.0	57.3	54.1	55.3	56.4
56	66.3	56.2	57.6	59.0	55.5	56.9	58.1	54.9	56.1	57.2
57	68.0	57.6	59.0	60.4	56.9	58.2	59.4	56.3	57.4	58.5
58	67.6	58.3	59.7	61.1	57.7	58.9	60.1	57.0	58.1	59.2
59	66.4	56.9	58.3	59.7	56.2	57.5	58.7	55.6	56.7	57.8
60	66.4	54.1	55.5	57.0	53.4	54.8	56.1	52.8	54.0	55.2
61	66.8	53.5	55.0	56.4	52.9	54.2	55.5	52.3	53.5	54.7
62	67.2	52.5	54.0	55.5	51.9	53.3	54.6	51.3	52.6	53.8
63	65.5	51.6	53.2	54.7	51.1	52.5	53.8	50.5	51.8	53.0
64	65.3	49.0	50.6	52.1	48.4	49.9	51.3	47.9	49.2	50.5
65	64.0	48.2	49.9	51.4	47.7	49.2	50.6	47.2	48.5	49.8
66	62.2	46.6	48.2	49.8	46.0	47.6	49.0	45.5	46.9	48.2
67	60.5	44.6	46.2	47.8	44.0	45.6	47.1	43.5	45.0	46.3
68	62.5	45.6	47.2	48.8	45.0	46.6	48.0	44.5	45.9	47.3
69	60.4	45.7	47.4	49.0	45.2	46.7	48.2	44.7	46.1	47.4

TABLE G10: OTHER WEATHER DATA.

Time (hr)	Barometric Pressure (in Hg)	Wind Speed (mph)	Wind Direction (degrees east from North)	Total Cloud Amount	Cloud Type
1	27.87	9	307	0	
2	27.88	7	254	2	altocumulus
3	27.88	8	264	1	altocumulus
4	27.88	8	282	0	
5	27.89	10	292	1	altocumulus
6	27.89	4	240	1	altocumulus
7	27.90	4	190	7	altocumulus
8	27.90	7	209	9	altocumulus
9	27.90	7	190	5	altocumulus
10	27.89	5	222	8	altocumulus
11	27.88	8	175	1	altocumulus
12	27.86	9	190	1	altocumulus
13	27.83	10	180	1	altocumulus
14	27.80	14	172	1	altocumulus
15	27.78	13	198	1	altocumulus
16	27.77	10	210	1	cumulus
17	27.75	3	210	1	cumulus
18	27.74	5	260	1	cumulus
19	27.73	0	0	1	stratocumulus
20	27.73	7	120	1	cirrus
21	27.73	6	102	1	cirrus
22	27.72	4	126	2	actocumulus
23	27.72	5	112	1	actocumulus
24	27.72	5	38	8	altocumulus
25	27.71	9	44	9	altocumulus
26	27.70	8	70	7	altocumulus
27	27.68	6	81	9	altocumulus
28	27.66	6	57	8	altocumulus
29	27.65	7	70	9	altocumulus
30	27.64	9	88	4	stratocumulus
31	27.63	7	73	7	cumulus
32	27.61	6	70	6	cumulus
33	27.59	9	140	3	cumulus
34	27.56	12	138	4	cumulus
35	27.53	16G22*	190	2	cumulus
36	27.50	16G22	200	1	cumulus
37	27.46	18G24	190	1	cumulus
38	27.43	16G22	190	4	cumulus
39	27.40	18G26	207	8	cumulus
40	27.37	16	194	3	cumulus
41	27.34	12	188	8	cumulonimbus
42	27.32	8	120	8	cumulonimbus
43	27.29	5	137	9	cumulonimbus
44	27.28	22	84	9	cumulonimbus

Cont'd.

TABLE G10: Continued

Time (hr)	Barometric Pressure (in Hg)	Wind Speed (mph)	Wind Direction (degrees east from North)	Total Cloud Amount	Cloud Type
45	27.23	15	91	10	stratocumulus
46	27.26	1	170	10	stratocumulus
47	27.32	39G53	336	10	stratocumulus
48	27.33	27G35	346	9	stratus fractus
49	27.34	6	30	10	stratus
50	27.36	12	329	10	stratus
51	27.36	11	330	9	stratus
52	27.35	10	325	9	stratus
53	27.36	8	278	9	stratus fractus
54	27.37	12	288	9	stratocumulus
55	27.36	18	277	9	stratocumulus
56	27.36	18G24	290	8	cumulus fractus
57	27.36	24G34	300	10	stratocumulus
58	27.38	22G40	308	10	stratus fractus
59	27.40	20G32	300	10	stratocumulus
60	27.42	18G26	318	10	stratocumulus
61	27.47	30G45	348	10	stratocumulus
62	27.52	28G36	340	10	stratocumulus
63	27.57	25G36	340	10	stratocumulus
64	27.62	32G41	355	10	stratocumulus
65	27.68	26	358	10	stratocumulus
66	27.72	29G36	345	10	stratocumulus
67	27.75	29G38	350	10	stratocumulus
68	27.79	27G38	350	10	stratocumulus
69	27.81	29G34	352	10	stratocumulus
70	27.83	21	350	10	cumulus fractus
71	27.84	16	355	10	stratocumulus
72	27.86	15	320	10	stratocumulus

* Gustiness is indicated by a G after the speed with the peak gust given after the G.

APPENDIX G11: OBSERVED AND PREDICTED SOLAR INTENSITY, BTU/(hr)(ft^2).

Time	Direct		Horizontal		Cloud Cover Over Sun (observed)	Total Cloud Amount (Model)
	Observed	Model	Observed	Model		
33.5	197.6		25.2		0	
34.0	217.3	169.3	72.4	89.5	0	4
34.5	0.5		42.0		9	
35.0	89.9	189.7	129.0	121.1	7	2
35.5	255.7		176.9		0	
36.0	258.3	199.4	179.4	142.9	0	1
36.5	264.8		196.7		0	
37.0	270.5	203.2	204.6	153.8	0	1
37.5	211.2		211.5		2	
38.0	273.6	197.5	207.7	149.5	0	4
38.5	268.3		172.5		0	
39.0	67.2	153.6	192.0	110.1	7	8
39.5	229.1		188.2		2	
40.0	260.9	188.3	180.3	120.4	0	3
40.5	252.2		151.1		0	
41.0	229.5	134.4	123.4	71.2	2	8
41.5	151.8		96.9		2	
42.0	18.3	109.8	38.7	43.4	7	8
42.5	0.5		34.6		10	
43.0	0.0	48.2	6.3	11.8	10	9
44.0	0.0		0.0		10	
57.0	42.3	74.5	30.8	28.9	8	10
57.5	174.5		124.3		4	
58.0	0.0	91.7	34.0	48.0	10	10
59.0		100.5	12.6	63.6		10
60.0		105.1	19.5	74.7		10
61.0	**	107.2	38.4	80.5	**	10
62.0		107.2	51.3	80.5		10
63.0		105.2	46.3	74.7		10
64.0		105.1	53.5	63.6		10
65.0		100.5	15.7	48.0		10

* observed cloud cover was estimated when readings were taken with the direct pyrheleometer as the cover over the sun at that time.

** clouding over quickly & precipitation.

TABLE G12: SWINE WEIGHTS.

Group	Individual hog weight (lb)	Number of hogs	Average Weight (lb)
I	13,27,4 @ 24	6	23
II	2 @ 31, 5 @ 33, 2 @ 35, 4 @ 37 7 @ 40	20	36
III	5 @ 42, 4 @ 44	9	43
IV	9 @ 53, 3 @ 55, 2 @ 57, 4 @ 60	18	55
V	2 @ 62, 3 @ 64, 14 @ 66,68	20	65
VI	71, 2 @ 73, 2 @ 74, 82, 2 @ 84	8	77
VII	5 @ 119, 121	6	119
VIII	132, 148, 159	3	146
IX	174, 179, 198	3	184
X	6 @ 250	6	250
Overall		99	74

APPENDIX H: PROCEDURES

H1: METHOD FOR CALCULATING RELATIVE HUMIDITY.

The procedure used was described by several references (2,40,37,14) and was carried out as follows:

$$RH = 100U/(1-((1-U)(PW_{db}/B)))$$

$$U = W/WS$$

$$WS = (0.622 \times PW_{db})/(B - PW_{db})$$

$$W = 4354. \text{ X } E /((B - E) \times 7000)$$

$$E = (PW_{db} - ((B - PW_{db}) \times (T_{db} - T_{wb}))/(2800. - (1.3 \times T_{wb})$$

where RH = relative humidity, %;

U = degree of saturation;

PW_{db} = saturation pressure at dry-bulb temperature, in Hg;

B = barometric pressure, in Hg;

W = absolute humidity of the air;

WS = absolute humidity of the air at saturation;

E = vapor pressure of air, in Hg;

PW_{wb} = saturation pressure at wet-bulb temperature, in Hg;

T_{db} = dry-bulb temperature, ^{o}F; and

T_{wb} = wet-bulb temperature, ^{o}F.

H2: METHOD FOR CALCULATING INWARD FLOWING FRACTION OF RADIATION ABSORBED BY THE INNER AND OUTER WINDOW PANE.

$$N_{io} = U/h_o$$

and $$N_{ii} = U/h_o + U/h_s$$

where N_{io} = the inward flowing fraction of the radiation absorbed by the outer pane;

N_{ii} = the inward flowing fraction of the radiation absorbed by the inner pane,

U = overall heat transfer coefficient for the windows,

h_o = surface heat transfer coefficient combining the effects of radiation and convection for the outer surface, and

h_s = surface heat transfer coefficient combining the effects of radiation and convection for the air space surface within the double-glazing.

APPENDIX I: VALIDATION INPUT FORMAT.

```
 1        2 39 92 40 82 93 66 90 700
 2      000
 3      000
 4      000
 5      000
 6      000
 7      000
 8            0  16000  16000  20000  20000  20000
 9       23 36 43 55 65 77119146184250
10        6 20  9 18 20  8  6  3  3  6
11       100 100
12       2787 2788 2788 2788 2789 2789 2790 2790 2790 2789 2788 2786 2783 2780 2778 2777
13       2775 2774 2773 2773 2773 2772 2772 2772 2771 2770 2768 2766 2765 2764 2763 2761
14       2759 2756 2753 2750 2746 2743 2740 2737 2734 2732 2729 2728 2723 2726 2732 2733
15       2734 2736 2736 2735 2736 2737 2736 2736 2736 2738 2740 2742 2747 2752 2757 2762
16       2768 2772 2775 2779 2781 2783 2784 2786
17        95 428 228 228 428 000  24  99 000  41 000 000  41 20712181218 000
18         3000    3000    3000    3000    3000    3000    3000    3000    3000    3000    3000
19         3000    3000    3000    3000    3000    3000    3000    3000    3000    3000    3000
20         3000    3000    3000    3000    3000    3000    3000    3000    3000    3000    3000
21         3000    3000    3000    3000    3000    3000    3000    3000    3000    3000    3000
22         3000    3000    3000    3000    3000    3000    3000    3000    3000    3000    3000
23         3000    3000    3000    3000    3000    3000    3000    3000    3000    3000    3000
24         3000    3000    3000    3000    3000    3000
25         03
26       400 000 146 163  90  92
27        0
28         0.00228   0.34559  -1.19908   2.22366  -2.05287   0.72376
29         0.01407   1.06226  -5.59131  12.15034 -11.78092   4.20070
30        -0.00401   0.74050   7.20350 -20.11763  19.68824  -6.74588
31        53.34 113.31 7. 1.EDMONTON
32         90.0   0.00  1  SOUTH WALL
33         90.0   90.0  2  WEST WALL
34         90.0  -90.0  3  EAST WALL
35         90.0  180.0  4  NORTH WALL
36        20.50   90.0  5  WEST SLOPE
37        20.50  -90.0  6  EAST SLOPE
38         0.00   0.00  7  HORIZONTAL
39        253 10 SEPT 73
40       1.02 0.20 .15 4.0 .67 .17
41       0 2 1 0 1 1 7 9 5 8 1 1 1 1 1 1 1 1 1 1 1 2 1 8
42       51.7 51.0 50.1 47.1 47.2 46.2 47.5 49.8 52.0 57.8 61.2 65.4
43       67.3 70.2 70.8 71.0 72.7 72.6 71.9 64.2 59.6 56.5 52.9 51.3
44       44.8 44.3 42.9 41.5 40.7 40.4 41.5 43.0 45.1 46.7 48.5 49.7
45       51.7 55.3 55.5 56.1 56.1 58.0 57.8 57.7 54.2 52.5 50.0 48.2
46        254 11 SEPT 73
47       1.02 0.20 .15 4.0 .67 .17
48       9 7 9 8 9 4 7 6 3 4 2 1 1 4 8 3 8 8 9 9101010 9
49       52.1 53.6 53.0 51.7 51.8 51.5 49.6 52.2 55.9 59.6 61.3 [illegible]
50       69.1 72.4 75.6 76.1 77.2 74.0 70.3 67.8 59.4 59.5 57.5 52.6
51       48.5 49.5 49.3 48.3 48.6 47.9 46.5 48.5 50.9 53.1 54.0 56.9
52       59.0 60.9 62.7 62.5 63.0 62.0 60.6 59.1 54.4 53.9 53.0 49.7
53        255 12 SEPT 73
54       1.02 0.20 .15 4.0 .67 .17
55      1010 9 9 9 9 9 810101010101010101010101010101010
56       51.8 51.7 50.4 49.9 50.3 49.0 48.7 49.1 50.4 50.6 48.0 44.3
57       44.4 43.3 42.4 39.0 39.0 37.3 35.4 33.3 33.7 33.8 33.8 33.7
58       48.8 48.8 47.7 47.2 47.6 46.0 45.3 45.2 46.6 46.6 43.9 39.9
```

APPENDIX I: Continued

```
 40.8 40.1 39.4 35.8 35.6 33.9 31.6 29.3 30.1 29.9 30.1 30.1
      1000 1 1
NUMERICAL DATA FOR WALLS
WALL COMPONENTS
     00027   1280000   171        214       0000 ALUMINUM SIDING
     00313     0066     34       029        0000 3/8" PLYWOOD
     01667     0022      325     0180       0000 BATT INSULATION 2.0"
     00000     00000     00000   00000       850 AIR CAVITY
     00313     0066     34       029        0000 3/8" PLYWOOD

10
      1000 2 1
NUMERICAL DATA FOR PITCHED ROOF
ROOF COMPONENTS
     00217     0430     7000     0220       0000 ASPHALT SHINGLES
     00313     0066     34       029        0000 3/8" PLYWOOD
   100000                                        AIR SPACE
     01667     0022      325     0180       0000 BATT INSULATION 2.0"
     00313     0066     34       029        0000 3/8" PLYWOOD

10
      1000 3 1
NUMERICAL DATA FOR HORIZONTAL ROOF
ROOF COMPONENTS
     00217     0430     7000     0220       0000 ASPHALT SHINGLES
     00313     0066     34       029        0000 3/8" PLYWOOD
                                             850 AIR SPACE
     01667     0022      325     0180       0000 BATT INSULATION 2.0"
     00313     0066     34       029        0000 3/8" PLYWOOD

10
      1000 4 1
NUMERICAL DATA FOR DOORS
DOOR COMPONENTS
     00313     0066     34       029        0000 3/8" PLYWOOD
     0125      0022      325     0180       0000 BATT INSULATION 1.5"
     00313     0066     34       029        0000 3/8" PLYWOOD

10

```

APPENDIX J: VALIDATION OUTPUT

J1. Numerical Component Data.

```
                    NUMERICAL DATA FOR WALLS
                    WALL COMPONENTS

LAYER THICKNESS   CONDUCTIVITY      DENSITY       SP HEAT          RESISTANCE
                                                                                     DESCRIPTION OF LAYER

  1    0.0027      128.0000        171.0000       0.2140             0.0             ALUMINUM SIDING
  2    0.0313        0.0660         34.0000       0.2900             0.0             3/8" PLYWOOD
  3    0.1667        0.0220          3.2500       0.1800             0.0             BATT INSULATION 2.0"
  4    0.0           0.0             0.0          0.0                0.8500          AIR CAVITY
  5    0.0313        0.0660         34.0000       0.2900             0.0             3/8" PLYWOOD

                       THERMAL CONDUCTANCE.   U= 0.107  BTUS/HR FT FT      DEGF

                            SAMPLING TIME INTERVAL.  DT=    1.000HR.

                                  COEFFICIENTS FOR RAMP INPUT

           J              D/B               1/B               A/B               D(Z)
           0           0.533267          0.072734          0.425630          1.000000
           1          -0.426787          0.033863         -0.319113         -0.000399
           2           0.000135          0.000019          0.000098          0.000000
           3          -0.000000          0.000000         -0.000000         -0.000000
           4           0.000000         -0.000000         -0.000000
```

J1. Continued

```
                    NUMERICAL DATA FOR PITCHED ROOF
                    ROOF COMPONENTS

LAYER THICKNESS    CONDUCTIVITY      DENSITY      SP HEAT        RESISTANCE
                                                                                DESCRIPTION OF LAYER
  1    0.0217        0.4300          70.0000      0.2200           0.0          ASPHALT SHINGLES
  2    0.0313        0.0660          34.0000      0.2900           0.0          3/8" PLYWOOD
  3    0.0           0.0              0.0         0.0              1.1311       AIR SPACE
  4    0.1667        0.0220           3.2500      0.1800           0.0          BATT INSULATION 2.0"
  5    0.0313        0.0660          34.0000      0.2900           0.0          3/8" PLYWOOD

                  THERMAL CONDUCTANCE.   U= 0.103  BTUS/HR FT FT      DEGF

                        SAMPLING TIME INTERVAL.  DT=    1.000HR.

                             COEFFICIENTS FOR RAMP INPUT

           J             D/B              1/B             A/B              D(Z)
           0          0.750060         0.067039        0.43[illegible]11       1.000000
           1         -0.647474         0.035871       -0.329929        -0.000665
           2          0.000361         0.000037        0.000165         0.000000
           3         -0.000000         0.000000       -0.000000        -0.000000
           4          0.000000         0.000000        0.000000
```

J1. Continued

```
                  NUMERICAL DATA FOR HORIZONTAL ROOF
                  ROOF COMPONENTS

LAYER THICKNESS    CONDUCTIVITY       DENSITY        SP HEAT          RESISTANCE       DESCRIPTION OF LAYER

  1    0.0217         0.4300          70.0000         0.2200             0.0            ASPHALT SHINGLES
  2    0.0313         0.0660          34.0000         0.2900             0.0            3/8" PLYWOOD
  3    0.0            0.0              0.0            0.0                0.8500         AIR SPACE
  4    0.1667         0.0220           3.2500         0.1800             0.0            BATT INSULATION 2.0"
  5    0.0313         0.0660          34.0000         0.2900             0.0            3/8" PLYWOOD

                    THERMAL CONDUCTANCE.   U= 0.106  BTUS/HR FT FT      DEGF

                          SAMPLING TIME INTERVAL.  DT=    1.000HR.

                               COEFFICIENTS FOR RAMP INPUT

          J             D/B              1/B              A/B              D(Z)
          0          0.754017         0.069773         0.434263         1.000000
          1         -0.648264         0.036228        -0.328361        -0.000522
          2          0.000279         0.000031         0.000129         0.000000
          3         -0.000000         0.000000        -0.000000        -0.000000
          4          0.000000        -0.000000        -0.000000
```

J1. Continued

```
                  NUMERICAL CATA FOR DOORS
                  DOOR COMPONENTS

LAYER THICKNESS    CONDUCTIVITY        DENSITY        SP HEAT          RESISTANCE
                                                                                          DESCRIPTION OF LAYER

  1    0.0313         0.0660          34.0000         0.2900              0.0             3/8" PLYWOOD
  2    0.1250         0.0220           3.2500         0.1800              0.0             BATT INSULATION 1.8"
  3    0.0313         0.0660          34.0000         0.2900              0.0             3/8" PLYWOOD

                      THERMAL CONDUCTANCE.   U= 0.151  BTUS/HR FT FT      DEGF

                            SAMPLING TIME INTERVAL.  DT=    1.000HR.

                               COEFFICIENTS FOR RAMP INPUT

            J            D/B               1/B               A/B               D(Z)
            0         0.461174          0.115996          0.461174          1.000000
            1        -0.310355          0.034825         -0.310355         -0.000009
            2         0.000002          0.000001          0.000002          0.000000
            3        -0.000000          0.000000         -0.000000         -0.000000
            4        -0.000000          0.000000         -0.000000
```

J2. Solar Parameters and Thermal Properties.

```
DATA FOR 10 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   2.540   DECLINATION =   4.911

SOUTH WALL   SURFACE TILT =  90.00  SURFACE AZIMUTH =   0.0

CLOCK TIME     1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00 12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00

SOLAR TIME     0.0   0.0   0.0   0.0   0.0   0.0   0.0  -5.51 -4.51 -3.51 -2.51 -1.51 -0.51  0.49  1.49  2.49  3.49  4.49  5.49  0.0

ALTITUDE        0.0   0.0   0.0   0.0   0.0   0.0   0.0   8.3  17.1  25.4  32.7  38.1  41.2  41.2  38.2  32.8  25.6  17.3   8.5   0.0

AZIMUTH         0.0   0.0   0.0   0.0   0.0   0.0   0.0 -87.1 -74.7 -61.3 -46.3 -29.2 -10.2   9.7  28.8  45.9  61.0  74.4  86.8   0.0

D. INTENSITY    0.0   0.0   0.0   0.0   0.0   0.0   0.0  49.1 135.6 134.7 191.3 199.8 203.6 203.7 200.0 191.5 175.4 144.3  76.3   0.0

DIRECT BEAM     0.0   0.0   0.0   0.0   0.0   0.0   0.0   2.5  34.2  58.4 111.2 137.2 150.9 151.0 137.6 111.9  76.7  37.1   4.2   0.0

SOLAR LOAD      0.0   0.0   0.0   0.0   0.0   0.0   0.0   7.9  54.7  84.0 154.0 186.8 204.2 204.4 187.4 154.9 110.2  59.0  12.7   0.0

S.H.G.F.        0.0   0.0   0.0   0.0   0.0   0.0   0.0   4.1  29.5  57.3 114.5 142.5 156.9 157.1 143.0 115.3  75.5  32.1   6.4   0.0

SOL. AIR    O  51.7  51.0  50.1  47.1  47.2  46.2  47.5  51.0  60.2  70.4  84.3  93.4  97.9 100.9  98.9  94.2  89.2  81.4  73.8  64.2

DRY BULB    O  51.7  51.0  50.1  47.1  47.2  46.2  47.5  49.8  52.0  57.8  61.2  65.4  67.3  70.2  70.8  71.0  72.7  72.6  71.9  64.2

WET BULB    O  44.8  44.3  42.9  41.5  40.7  40.4  41.5  43.0  45.1  46.7  48.5  49.7  51.7  55.3  55.5  56.1  58.1  58.0  57.8  57.7

LONG. RAD. O 108.2 107.7 107.0 104.6 104.5 103.7 104.6 107.0 111.9 118.6 127.0 133.7 137.3 140.3 139.8 137.6 135.7 131.8 127.6 119.9

SHORT RAD. O 108.1 107.5 106.8 104.3 104.4 103.5 104.6 109.7 130.2 146.9 178.0 194.9 203.6 206.4 200.1 167.3 171.1 150.5 131.3 119.1

CONV.       O  -0.5  -0.8  -0.9  -1.7  -0.7  -1.0  -0.2  -2.1 -16.1 -24.5 -46.4 -57.1 -63.6 -63.6 -59.5 -50.0 -35.7 -20.4  -5.9  -3.6

HEAT FLUX   O  -0.6  -1.0  -1.1  -2.1  -0.8  -1.2  -0.2   0.7   2.3   3.6   4.5   4.0   2.7   2.4   0.8  -0.2  -0.3  -1.7  -2.2  -4.4

SUR. TEMP. O  51.8  51.2  50.3  47.5  47.4  46.4  47.5  50.3  56.0  63.9  72.8  79.7  83.2  86.1  85.7  83.5  81.6  77.7  73.4  68.1

SUR. TEMP. I  58.2  57.7  57.0  55.0  54.3  53.6  54.0  55.8  58.5  62.9  66.9  70.7  73.1  75.7  76.6  76.9  77.7  77.5  76.7  71.7

HEAT FLUX   I  -0.6  -0.5  -0.5  -0.1  -0.5  -0.5  -0.9  -1.3  -1.3  -1.6  -0.9  -0.5   0.2   0.2   0.7   0.7   0.2   0.2   0.1   1.2

CONV.       I  -0.6  -0.5  -0.5  -0.1  -0.5  -0.5  -0.9  -1.3  -1.3  -1.6  -0.9  -0.5   0.2   0.2   0.7   0.7   0.2   0.2   0.1   1.2

DRY BULB    I  58.6  58.0  57.3  56.1  54.7  53.9  54.6  56.7  59.4  64.0  67.8  71.1  72.9  75.6  76.1  76.4  77.8  77.4  76.6  70.9
```

J2. Continued

```
DATA FOR 10 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON
EQUATION OF TIME =   2.540   DECLINATION =    4.911
SOUTH WALL   SURFACE TILT =  90.00  SURFACE AZIMUTH =   0.0
CLOCK TIME   21.00 22.00 23.00 24.00
SOLAR TIME     0.0   0.0   0.0   0.0
ALTITUDE        0.0   0.0   0.0   0.0
AZIMUTH         0.0   0.0   0.0   0.0
C. INTENSITY    0.0   0.0   0.0   0.0
DIRECT BEAM     0.0   0.0   0.0   0.0
SOLAR LOAD      0.0   0.0   0.0   0.0
S.H.G.F.        0.0   0.0   0.0   0.0
SOL. AIR    O  59.6  56.5  52.9  51.3
DRY BULB    O  59.6  56.5  52.9  51.3
WET BULB    O  54.2  52.5  50.0  48.2
LONG. RAD. O 115.5 112.6 109.5 108.0
SHORT RAD. O 1[illegible].9 112.2 109.1 107.8
CONV.       O  -2.5  -1.9  -2.0  -1.3
HEAT FLUX  O  -3.0  -2.2  -2.4  -1.6
SUR. TEMP. O  60.2  57.0  53.4  51.6
SUR. TEMP. I  67.2  64.0  60.7  58.7
HEAT FLUX  I   0.9   0.4   0.4  -0.0
CONV.       I   0.9   0.4   0.4  -0.0
DRY BULB    I  66.6  63.7  60.5  58.7
```

J2. Continued

```
DATA FOR 10 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON
EQUATION OF TIME =   2.540   DECLINATION =   4.911
WEST WALL    SURFACE TILT =  90.00  SURFACE AZIMUTH =  90.00
CLOCK TIME     1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00 12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00
SOLAR TIME    0.0   0.0   0.0   0.0   0.0   0.0   0.0  -5.51 -4.51 -3.51 -2.51 -1.51 -0.51  0.49  1.49  2.49  3.49  4.49  5.49  0.0
ALTITUDE       0.0   0.0   0.0   0.0   0.0   0.0   0.0   8.3  17.1  25.4  32.7  38.1  41.2  41.2  38.2  32.8  25.6  17.3   8.5   0.0
AZIMUTH        0.0   0.0   0.0   0.0   0.0   0.0   0.0 -87.1 -74.7 -61.3 -46.3 -29.2 -10.2   9.7  28.8  45.9  61.0  74.4  86.8   0.0
D. INTENSITY   0.0   0.0   0.0   0.0   0.0   0.0   0.0  49.1 135.6 134.7 191.3 199.8 203.6 203.7 200.0 191.5 175.4 144.3  76.3   0.0
DIRECT BEAM    0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0  25.9  75.7 115.7 138.4 132.7  75.4   0.0
SOLAR LOAD     0.0   0.0   0.0   0.0   0.0   0.0   0.0   4.8  17.2  20.7  33.6  38.2  41.6  69.9 120.5 159.0 177.1 162.6  89.5   0.0
S.H.G.F.       0.0   0.0   0.0   0.0   0.0   0.0   0.0   3.4  12.4  14.9  24.2  27.5  30.0  37.0  78.5 119.1 137.5 128.3  70.8   0.0
SOL. AIR    O  51.7  51.0  50.1  47.1  47.2  46.2  47.5  50.5  54.6  60.9  66.2  71.1  73.5  80.7  88.9  94.9  99.3  97.0  85.3  64.2
DRY BULB    O  51.7  51.0  50.1  47.1  47.2  46.2  47.5  49.8  52.0  57.8  61.2  65.4  67.3  70.2  70.8  71.0  72.7  72.6  71.9  64.2
WET BULB    O  44.8  44.3  42.9  41.5  40.7  40.4  41.5  43.0  45.1  46.7  48.5  49.7  51.7  55.3  55.5  56.1  58.1  58.0  57.8  57.7
LONG. RAD.  O 108.2 107.7 107.0 104.6 104.5 103.7 104.6 106.8 109.4 114.5 118.5 122.7 124.9 129.6 134.1 137.5 140.6 139.7 133.7 120.4
SHORT RAD.  O 108.1 107.5 106.8 104.3 104.4 103.5 104.6 108.4 115.2 121.6 129.8 135.5 138.6 152.6 173.4 189.0 197.8 191.9 162.0 119.1
CONV.       O  -0.5  -0.8  -0.9  -1.7  -0.7  -1.0  -0.2  -1.1  -4.9  -4.9  -9.5 -10.9 -12.8 -20.8 -36.9 -49.3 -64.9 -61.8 -30.7  -5.5
HEAT FLUX   O  -0.6  -1.0  -1.1  -2.1  -0.8  -1.2  -0.2   0.5   0.9   2.2   1.8   1.9   0.9   2.2   2.4   2.1   2.3   0.4  -2.3  -6.8
SUR. TEMP.  O  51.8  51.2  50.3  47.5  47.4  46.4  47.5  50.1  53.2  59.0  63.6  68.1  70.5  75.4  80.0  83.3  86.4  85.6  79.6  65.6
SUR. TEMP.  I  58.2  57.7  57.0  55.0  54.3  53.6  54.0  55.8  58.4  62.7  66.4  70.1  72.2  74.9  76.0  76.7  77.8  77.9  77.1  71.9
HEAT FLUX   I  -0.6  -0.5  -0.5  -0.1  -0.5  -0.5  -0.9  -1.3  -1.5  -1.9  -1.6  -1.5  -1.0  -1.0  -0.1   0.4   0.5   0.8   0.7   1.5
CONV.       I  -0.6  -0.5  -0.5  -0.1  -0.5  -0.5  -0.9  -1.3  -1.5  -1.9  -1.6  -1.5  -1.0  -1.0  -0.1   0.4   0.5   0.8   0.7   1.5
DRY BULB    I  58.6  58.0  57.3  56.1  54.7  53.9  54.6  56.7  59.4  64.0  67.5  71.1  72.9  75.6  76.1  76.4  77.5  77.4  76.6  70.9
```

J2. Continued

```
DATA FOR 19 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   2.540   DECLINATION =   4.911

WEST WALL    SURFACE TILT =  90.00  SURFACE AZIMUTH =  90.00

CLOCK TIME    21.00 22.00 23.00 24.00

SOLAR TIME     0.0   0.0   0.0   0.0

ALTITUDE        0.0   0.0   0.0   0.0

AZIMUTH         0.0   0.0   0.0   0.0

D. INTENSITY    0.0   0.0   0.0   0.0

DIRECT BEAM     0.0   0.0   0.0   0.0

SOLAR LOAD      0.0   0.0   0.0   0.0

S.H.G.F.        0.0   0.0   0.0   0.0

SOL. AIR    O  59.6  56.5  52.9  51.3

DRY BULB    O  59.6  56.5  52.9  51.3

WET BULB    O  54.2  52.5  50.0  48.2

LONG. RAD. O 115.5 112.6 109.5 108.0

SHORT RAD. O 114.9 112.2 109.1 107.8

CONV.       O  -2.6  -1.9  -2.0  -1.3

HEAT FLUX  O  -3.2  -2.3  -2.4  -1.6

SUR. TEMP. O  60.3  57.0  53.4  51.6

SUR. TEMP. I  67.2  64.0  60.7  58.7

HEAT FLUX  I   0.9   0.4   0.4  -0.0

CONV.       I   0.9   0.4   0.4  -0.0

DRY BULB    I  66.6  63.7  60.5  58.7
```

J2. Continued

```
DATA FOR 10 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   2.540   DECLINATION =   4.911

EAST WALL    SURFACE TILT =  90.00  SURFACE AZIMUTH = -90.00

CLOCK TIME     1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00 12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00

SOLAR TIME    0.0   0.0   0.0   0.0   0.0   0.0   0.0  -5.51 -4.51 -3.51 -2.51 -1.51 -0.51  0.49  1.49  2.49  3.49  4.49  5.49  0.0

ALTITUDE       0.0   0.0   0.0   0.0   0.0   0.0   0.0   8.3  17.1  25.4  32.7  38.1  41.2  41.2  38.2  32.8  25.6  17.3   8.5   0.0

AZIMUTH        0.0   0.0   0.0   0.0   0.0   0.0   0.0 -87.1 -74.7 -61.3 -46.3 -29.2 -10.2   9.7  28.8  45.9  61.0  74.4  86.8   0.0

D. INTENSITY   0.0   0.0   0.0   0.0   0.0   0.0   0.0  49.1 135.6 134.7 191.3 199.8 203.6 203.7 200.0 191.5 175.4 144.3  76.3   0.0

DIRECT BEAM    0.0   0.0   0.0   0.0   0.0   0.0   0.0  48.5 125.0 106.7 116.5  76.8  27.1   0.0   0.0   0.0   0.0   0.0   0.0   0.0

SOLAR LOAD     0.0   0.0   0.0   0.0   0.0   0.0   0.0  57.6 153.0 136.4 159.7 121.6  71.2  41.7  38.3  33.7  27.1  18.4   7.4   0.0

S.H.G.F.       0.0   0.0   0.0   0.0   0.0   0.0   0.0  45.6 120.8 105.9 119.8  79.6  37.6  30.0  27.6  24.3  19.5  13.2   5.4   0.0

SOL. AIR   O  51.7  51.0  50.1  47.1  47.2  46.2  47.5  58.4  75.0  78.3  85.2  83.6  78.0  76.5  76.5  76.1  76.8  75.4  73.0  64.2

DRY BULB   O  51.7  51.0  50.1  47.1  47.2  46.2  47.5  49.8  52.0  57.8  61.2  65.4  67.3  70.2  70.8  71.0  72.7  72.6  71.9  64.2

WET BULB   O  44.8  44.3  42.9  41.5  40.7  40.4  41.5  43.0  45.1  46.7  48.5  49.7  51.7  55.3  55.5  56.1  58.1  58.0  57.8  57.7

LONG. RAD. O 108.2 107.7 107.0 104.6 104.5 103.7 104.6 110.1 116.5 122.9 127.8 129.2 127.4 127.8 128.1 128.0 129.0 128.4 127.0 119.8

SHORT RAD. O 108.1 107.5 106.8 104.3 104.4 103.5 104.6 129.5 169.6 167.9 180.2 168.8 150.4 141.3 140.5 138.9 137.8 134.2 129.2 119.1

CONV.      O  -0.5  -0.8  -0.9  -1.7  -0.7  -1.0  -0.2 -16.8 -46.4 -42.3 -49.4 -38.4 -23.6 -13.4 -12.4 -11.2  -8.5  -6.4  -3.3  -3.4

HEAT FLUX  O  -0.6  -1.0  -1.1  -2.1  -0.8  -1.2  -0.2   2.6   4.7   2.7   3.0   1.2  -0.6   0.1  -0.0  -0.3   0.2  -0.6  -1.1  -4.1

SUR. TEMP. O  51.8  51.2  50.3  47.5  47.4  46.4  47.5  54.0  63.6  68.4  73.6  75.0  73.2  73.5  73.9  73.8  74.8  74.2  72.7  68.0

SUR. TEMP. I  58.2  57.7  57.0  55.0  54.3  53.6  54.0  56.0  58.9  63.3  67.0  70.6  72.6  75.0  75.8  76.1  77.1  77.2  76.5  71.7

HEAT FLUX  I  -0.6  -0.5  -0.5  -0.1  -0.5  -0.5  -0.9  -1.1  -0.8  -1.0  -0.7  -0.7  -0.5  -0.9  -0.5  -0.4  -0.6  -0.3  -0.1   1.1

CONV.      I  -0.6  -0.5  -0.5  -0.1  -0.5  -0.5  -0.9  -1.1  -0.8  -1.0  -0.7  -0.7  -0.5  -0.9  -0.5  -0.4  -0.6  -0.3  -0.1   1.1

DRY BULB   I  58.6  58.0  57.3  56.1  54.7  53.9  54.6  56.7  59.4  64.0  67.5  71.1  72.9  75.6  76.1  76.4  77.8  77.4  76.6  70.9
```

J2. Continued

```
DATA FOR 10 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   2.540   DECLINATION =   4.911

EAST WALL    SURFACE TILT =  90.00  SURFACE AZIMUTH = -90.00

CLOCK TIME   21.00 22.00 23.00 24.00

SOLAR TIME    0.0   0.0   0.0   0.0

ALTITUDE        0.0   0.0   0.0   0.0

AZIMUTH         0.0   0.0   0.0   0.0

D. INTENSITY    0.0   0.0   0.0   0.0

DIRECT BEAM     0.0   0.0   0.0   0.0

SOLAR LOAD      0.0   0.0   0.0   0.0

S.H.G.F.        0.0   0.0   0.0   0.0

SOL. AIR    O  59.6  56.5  52.9  51.3

DRY BULB    O  59.6  56.5  52.9  51.3

WET BULB    O  54.2  52.5  50.0  48.2

LONG. RAD. O 115.4 112.6 109.5 106.0

SHORT RAD. O 114.9 112.2 109.1 107.8

CONV.       O  -2.4  -1.9  -2.0  -1.3

HEAT FLUX   O  -3.0  -2.2  -2.4  -1.6

SUR. TEMP. O  60.2  57.0  53.4  51.6

SUR. TEMP. I  67.2  64.0  60.7  58.7

HEAT FLUX   I   0.8   0.4   0.4  -0.0

CONV.       I   0.8   0.4   0.4  -0.0

DRY BULB    I  66.6  63.7  60.5  58.7
```

J2. Continued

```
DATA FOR 10 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   2.540   DECLINATION =   4.911

NORTH WALL   SURFACE TILT =  90.00  SURFACE AZIMUTH = 180.00

CLOCK TIME      1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00 12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00

SOLAR TIME      0.0   0.0   0.0   0.0   0.0   0.0   0.0  -5.51 -4.51 -3.51 -2.51 -1.51 -0.51  0.49  1.49  2.49  3.49  4.49  5.49  0.0

ALTITUDE         0.0   0.0   0.0   0.0   0.0   0.0   0.0   8.3  17.1  25.4  32.7  38.1  41.2  41.2  38.2  32.8  25.6  17.3   8.5   0.0

AZIMUTH          0.0   0.0   0.0   0.0   0.0   0.0   0.0 -87.1 -74.7 -61.3 -46.3 -29.2 -10.2   9.7  28.8  45.9  61.0  74.4  86.8   0.0

D. INTENSITY     0.0   0.0   0.0   0.0   0.0   0.0   0.0  49.1 135.6 134.7 191.3 199.8 203.6 203.7 200.0 191.5 175.4 144.3  76.3   0.0

DIRECT BEAM      0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0

SOLAR LOAD       0.0   0.0   0.0   0.0   0.0   0.0   0.0   5.2  17.2  20.7  33.6  38.2  40.6  40.7  38.3  33.7  27.1  18.4   8.1   0.0

S.H.G.F.         0.0   0.0   0.0   0.0   0.0   0.0   0.0   3.7  12.4  14.9  24.2  27.5  29.3  29.3  27.6  24.3  19.5  13.2   5.8   0.0

SOL. AIR    O   51.7  51.0  50.1  47.1  47.2  46.2  47.5  50.6  54.6  60.9  66.2  71.1  73.4  76.3  76.5  76.1  76.8  75.4  73.1  64.2

DRY BULB    O   51.7  51.0  50.1  47.1  47.2  46.2  47.5  49.8  52.0  57.8  61.2  65.4  67.3  70.2  70.8  71.0  72.7  72.6  71.9  64.2

WET BULB    O   44.8  44.3  42.9  41.5  40.7  40.4  41.5  43.0  45.1  46.7  48.5  49.7  51.7  55.3  55.5  56.1  58.1  58.0  57.6  57.7

LONG. RAD.  O  108.2 107.7 107.0 104.6 104.5 103.7 104.6 106.8 109.4 114.5 118.5 122.7 124.8 127.5 128.1 128.0 129.0 128.4 127.0 119.8

SHORT RAD.  O  108.1 107.5 106.8 104.3 104.4 103.5 104.6 108.6 115.2 121.6 129.8 135.5 138.2 140.9 140.5 138.9 137.8 134.2 129.4 119.1

CONV.       O   -0.5  -0.8  -0.9  -1.7  -0.7  -1.0  -0.2  -1.2  -4.9  -4.9  -9.5 -10.9 -12.5 -12.2 -12.3 -11.2  -8.5  -6.4  -3.4  -3.4

HEAT FLUX   O   -0.6  -1.0  -1.1  -2.1  -0.8  -1.2  -0.2   0.5   0.9   2.2   1.8   1.9   0.9   1.1   0.1  -0.3   0.2  -0.6  -1.0  -4.2

SUR. TEMP.  O   51.8  51.2  50.3  47.5  47.4  46.4  47.5  50.1  53.2  59.0  63.6  68.1  70.4  73.3  73.9  73.8  74.8  74.2  72.8  65.0

SUR. TEMP.  I   58.2  57.7  57.0  55.0  54.3  53.6  54.0  55.8  58.4  62.7  66.4  70.1  72.2  74.8  75.8  76.1  77.1  77.2  76.5  71.7

HEAT FLUX   I   -0.6  -0.5  -0.5  -0.1  -0.5  -0.5  -0.9  -1.3  -1.5  -1.9  -1.6  -1.5  -1.0  -1.1  -0.5  -0.4  -0.6  -0.3  -0.1   1.1

CONV.       I   -0.6  -0.5  -0.5  -0.1  -0.5  -0.5  -0.9  -1.3  -1.5  -1.9  -1.6  -1.5  -1.0  -1.1  -0.5  -0.4  -0.6  -0.3  -0.1   1.1

DRY BULB    I   58.6  58.0  57.3  55.1  54.7  53.9  54.6  56.7  59.4  64.0  67.8  71.1  72.9  75.6  76.1  76.4  77.5  77.4  76.6  70.9
```

J2. Continued

```
DATA FOR 10 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   2.540   DECLINATION =   4.911

NORTH WALL   SURFACE TILT =  90.00  SURFACE AZIMUTH = 180.00

CLOCK TIME    21.00 22.00 23.00 24.00

SOLAR TIME     0.0   0.0   0.0   0.0

ALTITUDE        0.0   0.0   0.0   0.0

AZIMUTH         0.0   0.0   0.0   0.0

D. INTENSITY    0.0   0.0   0.0   0.0

DIRECT BEAM     0.0   0.0   0.0   0.0

SOLAR LOAD      0.0   0.0   0.0   0.0

S.H.G.F.        0.0   0.0   0.0   0.0

SOL. AIR    O  59.6  56.5  52.9  51.3

DRY BULB    O  59.6  56.5  52.9  51.3

WET BULB    O  54.2  52.5  50.0  48.2

LONG. RAD. O 115.4 112.6 109.5 108.0

SHORT RAD. O 114.9 112.2 109.1 107.8

CONV.       O  -2.5  -1.9  -2.0  -1.3

HEAT FLUX  O  -3.0  -2.2  -2.4  -1.6

SUR. TEMP. O  60.2  57.0  53.4  51.6

SUR. TEMP. I  67.2  64.C  60.7  58.7

HEAT FLUX  I   0.8   0.4   0.4  -0.0

CONV.       I   0.8   0.4   0.4  -0.0

DRY BULB    I  66.6  63.7  60.8  58.7
```

J2. Continued

```
DATA FOR 10 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   2.540   DECLINATION =   4.911

WEST SLOPE   SURFACE TILT =  20.50  SURFACE AZIMUTH =  90.00

CLOCK TIME     1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00 12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00

SOLAR TIME     0.0   0.0   0.0   0.0   0.0   0.0   0.0  -5.51 -4.51 -3.51 -2.51 -1.51 -0.51  0.49  1.49  2.49  3.49  4.49  5.49  0.0

ALTITUDE        0.0   0.0   0.0   0.0   0.0   0.0   0.0   8.3  17.1  25.4  32.7  38.1  41.2  41.2  38.2  32.8  25.6  17.3   8.5   0.0

AZIMUTH         0.0   0.0   0.0   0.0   0.0   0.0   0.0 -87.1 -74.7 -61.3 -46.3 -29.2 -10.2   9.7  28.8  45.9  61.0  74.4  86.8   0.0

D. INTENSITY    0.0   0.0   0.0   0.0   0.0   0.0   0.0  49.1 135.6 134.7 191.3 199.8 203.6 203.7 200.0 191.5 175.4 144.3  76.3   0.0

DIRECT BEAM     0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0  16.8  55.9  88.7 116.1 134.7 142.4 137.7 119.5  86.7  37.0   0.0

SOLAR LOAD      0.0   0.0   0.0   0.0   0.0   0.0   0.0   5.0  14.1  30.9  76.0 109.8 137.6 156.3 163.6 157.9 137.8 101.7  44.8   0.0

S.H.G.F.        0.0   0.0   0.0   0.0   0.0   0.0   0.0   3.6  10.1  13.5  42.2  76.0 102.4 119.7 126.6 122.3 106.0  76.6  31.7   0.0

SOL. AIR    O  51.7  51.0  50.1  47.1  47.2  46.2  47.5  50.1  51.8  61.5  68.4  77.7  83.7  89.4  91.1  90.5  89.2  83.6  74.4  64.2

DRY BULB    O  51.7  51.0  50.1  47.1  47.2  46.2  47.5  49.8  52.0  57.8  61.2  65.4  67.3  70.2  70.8  71.0  72.7  72.6  71.9  64.2

WET BULB    O  44.8  44.3  42.9  41.5  40.7  40.4  41.5  43.0  45.1  46.7  48.5  49.7  51.7  55.3  55.5  56.1  58.1  58.0  57.8  57.7

LONG. RAD.  O 109.4 108.9 108.2 105.8 105.6 104.9 105.7 108.2 111.3 118.3 128.0 137.5 144.5 150.8 153.2 152.8 151.2 145.6 136.0 122.2

SHORT RAD.  O 109.3 108.7 107.9 105.4 105.5 104.7 105.7 111.8 121.1 139.9 179.9 211.5 236.1 254.1 260.7 256.2 241.4 211.7 164.3 120.4

CONV.       O  -0.5  -0.9  -1.0  -2.2  -0.8  -1.1  -0.0  -2.3  -7.9 -16.4 -44.5 -66.4 -85.6 -97.5-104.0-101.6 -89.3 -68.4 -34.1  -8.1

HEAT FLUX   O  -0.6  -1.1  -1.3  -2.6  -0.9  -1.4   0.0   1.3   2.0   5.2   7.4   7.6   6.0   5.8   3.5   1.7   0.8  -2.3  -5.7 -10.8

SUR. TEMP.  O  51.8  51.2  50.4  47.6  47.4  46.5  47.5  50.4  54.0  61.9  72.3  82.0  88.7  94.6  96.8  96.4  95.0  89.7  80.4  66.2

SUR. TEMP.  I  58.3  57.7  57.0  55.1  54.4  53.6  54.1  55.9  58.5  62.9  66.8  70.8  73.2  76.1  77.1  77.5  78.4  78.3  77.2  71.9

HEAT FLUX   I  -0.6  -0.5  -0.4  -0.0  -0.5  -0.4  -0.9  -1.3  -1.5  -1.8  -1.1  -0.5   0.5   0.8   1.6   1.8   1.5   1.4   1.0   1.7

CONV.       I  -0.6  -0.5  -0.4  -0.0  -0.5  -0.4  -0.9  -1.3  -1.5  -1.8  -1.1  -0.5   0.5   0.8   1.6   1.8   1.5   1.4   1.0   1.7

DRY BULB    I  58.6  58.0  57.3  55.1  54.7  53.9  54.6  56.7  59.4  64.0  67.5  71.1  72.9  75.6  76.1  76.4  77.5  77.4  76.6  70.9
```

J2. Continued

```
DATA FOR 10 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   2.540   DECLINATION =   4.911

WEST SLOPE   SURFACE TILT =  20.50  SURFACE AZIMUTH =  90.00

CLOCK TIME   21.00 22.00 23.00 24.00

SOLAR TIME     0.0   0.0   0.0   0.0

ALTITUDE         0.0   0.0   0.0   0.0

AZIMUTH          0.0   0.0   0.0   0.0

D. INTENSITY     0.0   0.0   0.0   0.0

DIRECT BEAM      0.0   0.0   0.0   0.0

SOLAR LOAD       0.0   0.0   0.0   0.0

S.H.G.F.         0.0   0.0   0.0   0.0

SOL. AIR    O  59.6  56.5  52.9  51.3

DRY BULB    O  59.6  56.5  52.9  51.3

WET BULB    O  54.2  52.5  50.0  48.2

LONG. RAD. O 117.0 114.0 110.9 109.3

SHORT RAD. O 116.2 113.4 110.3 108.9

CONV.       O  -3.7  -2.5  -2.6  -1.6

HEAT FLUX   O  -4.5  -3.0  -3.2  -2.0

SUR. TEMP. O  60.5  57.1  53.6  51.7

SUR. TEMP. I  67.2  64.0  60.8  58.7

HEAT FLUX   I   1.1   0.5   0.4   0.0

CONV.       I   1.1   0.5   0.4   0.0

DRY BULB    I  66.6  63.7  60.5  58.7
```

J2. Continued

```
DATA FOR 10 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31  TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   2.540   DECLINATION =   4.911

EAST SLOPE   SURFACE TILT =  20.50  SURFACE AZIMUTH = -90.00

CLOCK TIME     1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00 12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00

SOLAR TIME     0.0   0.0   0.0   0.0   0.0   0.0   0.0  -5.51 -4.51 -3.51 -2.51 -1.51 -0.51  0.49  1.49  2.49  3.49  4.49  5.49  0.0

ALTITUDE        0.0   0.0   0.0   0.0   0.0   0.0   0.0   8.3  17.1  25.4  32.7  38.1  41.2  41.2  38.2  32.8  25.6  17.3   8.5   0.0

AZIMUTH         0.0   0.0   0.0   0.0   0.0   0.0   0.0 -87.1 -74.7 -61.3 -46.3 -29.2 -10.2   9.7  28.8  45.9  61.0  74.4  86.8   0.0

D. INTENSITY    0.0   0.0   0.0   0.0   0.0   0.0   0.0  49.1 135.6 134.7 191.3 199.8 203.6 203.7 200.0 191.5 175.4 144.3  76.3   0.0

DIRECT BEAM     0.0   0.0   0.0   0.0   0.0   0.0   0.0  23.6  81.2  91.5 137.4 142.5 135.0 116.6  89.4  56.7  22.6   0.0   0.0   0.0

SOLAR LOAD      0.0   0.0   0.0   0.0   0.0   0.0   0.0  28.7  95.2 105.6 157.6 163.6 156.6 138.2 110.6  76.8  40.9  15.0   7.8   0.0

S.H.G.F.        0.0   0.0   0.0   0.0   0.0   0.0   0.0  20.2  71.7  81.2 122.1 126.6 120.0 102.9  75.8  42.9  17.9  10.8   5.6   0.0

SOL. AIR    O  51.7  51.0  50.1  47.1  47.2  46.2  47.5  53.6  63.9  72.7  80.6  85.7  86.6  86.7  83.2  78.3  74.6  70.6  68.9  64.2

DRY BULB    O  51.7  51.0  50.1  47.1  47.2  46.2  47.5  49.8  52.0  57.8  61.2  65.4  67.3  70.2  70.8  71.0  72.7  72.6  71.9  64.2

WET BULB    O  44.8  44.3  42.9  41.5  40.7  40.4  41.5  43.0  45.1  46.7  48.5  49.7  51.7  55.3  55.5  56.1  58.1  58.0  57.8  57.7

LONG. RAD. O 109.4 108.9 108.2 105.8 105.6 104.9 105.7 111.2 122.2 129.7 141.0 147.0 148.4 148.4 144.8 139.7 135.4 131.2 129.2 121.5

SHORT RAD. O 109.3 108.7 107.9 105.4 105.5 104.7 105.7 131.2 187.6 201.2 246.8 255.6 251.6 239.3 217.2 189.7 161.9 140.5 134.0 120.4

CONV.       O  -0.5  -0.9  -1.0  -2.2  -0.8  -1.1  -0.0 -16.1 -56.7 -65.1 -96.6-102.7-100.4 -88.9 -73.1 -52.4 -28.9 -12.3  -6.6  -4.9

HEAT FLUX   O  -0.6  -1.1  -1.3  -2.6  -0.9  -1.4   0.0   3.9   8.8   6.4   9.3   5.9   2.9   2.0  -0.8  -2.5  -2.4  -2.9  -1.7  -6.1

SUR. TEMP.  O  51.8  51.2  50.4  47.6  47.4  46.5  47.5  53.8  66.2  74.1  85.3  91.1  92.4  92.4  89.1  84.1  79.9  75.7  73.2  65.4

SUR. TEMP.  I  58.3  57.7  57.0  55.1  54.4  53.6  54.1  56.0  59.0  63.6  67.6  71.4  73.6  73.6  76.4  76.9  77.6  77.4  76.6  71.7

HEAT FLUX   I  -0.6  -0.5  -0.4  -0.0  -0.5  -0.4  -0.9  -1.1  -0.7  -0.7   0.1   0.5   1.2   1.9   0.5   0.8   0.2   0.0   0.0   1.3

CONV.       I  -0.6  -0.5  -0.4  -0.0  -0.5  -0.4  -0.9  -1.1  -0.7  -0.7   0.1   0.5   1.2  -3.2   0.5   0.8   0.2   0.0   0.0   1.3

DRY BULB    I  58.6  58.0  57.3  56.1  54.7  53.9  54.6  56.7  59.4  64.0  67.8  71.1  72.9  75.6  76.1  76.4  77.8  77.4  76.6  70.9
```

J2. Continued

```
DATA FOR 10 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON
EQUATION OF TIME =   2.540   DECLINATION =   4.911
EAST SLOPE   SURFACE TILT =  20.50  SURFACE AZIMUTH = -90.00
CLOCK TIME   21.00 22.00 23.00 24.00
SOLAR TIME    0.0   0.0   0.0   0.0
ALTITUDE       0.0   0.0   0.0   0.0
AZIMUTH        0.0   0.0   0.0   0.0
D. INTENSITY   0.0   0.0   0.0   0.0
DIRECT BEAM    0.0   0.0   0.0   0.0
SOLAR LOAD     0.0   0.0   0.0   0.0
S.H.G.F.       0.0   0.0   0.0   0.0
SOL. AIR   O  59.6  56.5  52.9  51.3
DRY BULB   O  59.6  56.5  52.9  51.3
WET BULB   O  54.2  52.5  50.0  48.2
LONG. RAD. O 116.9 114.0 110.9 109.3
SHORT RAD. O 116.2 113.4 110.3 108.9
CONV.      O  -3.4  -2.5  -2.6  -1.6
HEAT FLUX  O  -4.1  -3.0  -3.2  -2.0
SUR. TEMP. O  60.4  57.1  53.6  51.7
SUR. TEMP. I  67.2  64.0  60.8  58.7
HEAT FLUX  I   1.0   0.5   0.4   0.0
CONV.      I   1.0   0.5   0.4   0.0
DRY BULB   I  66.6  63.7  60.8  58.7
```

J2. Continued

```
DATA FOR 10 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME.=   2.540   DECLINATION =   4.911

HORIZONTAL   SURFACE TILT =   0.0   SURFACE AZIMUTH =   0.0

CLOCK TIME     1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00 12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00

SOLAR TIME     0.0   0.0   0.0   0.0   0.0   0.0   0.0  -5.51 -4.51 -3.51 -2.51 -1.51 -0.51  0.49  1.49  2.49  3.49  4.49  5.49  0.0

ALTITUDE        0.0   0.0   0.0   0.0   0.0   0.0   0.0   8.3  17.1  25.4  32.7  38.1  41.2  41.2  36.2  32.8  25.6  17.3   8.5   0.0

AZIMUTH         0.0   0.0   0.0   0.0   0.0   0.0   0.0 -87.1 -74.7 -61.3 -46.3 -29.2 -10.2   9.7  28.8  45.9  61.0  74.4  86.8   0.0

D. INTENSITY    0.0   0.0   0.0   0.0   0.0   0.0   0.0  49.1 135.6 134.7 191.3 199.8 203.6 203.7 200.0 191.5 175.4 144.3  76.3   0.0

DIRECT BEAM     0.0   0.0   0.0   0.0   0.0   0.0   0.0   7.1  40.0  57.8 103.2 123.4 134.0 134.2 123.8 103.8  75.8  43.0  11.3   0.0

SOLAR LOAD      0.0   0.0   0.0   0.0   0.0   0.0   0.0  12.2  54.1  71.9 123.2 144.3 155.3 155.4 144.7 123.8  94.2  58.1  19.3   0.0

S.H.G.F.        0.0   0.0   0.0   0.0   0.0   0.0   0.0   5.4  30.2  48.4  90.3 109.2 118.9 119.0 109.6  90.8  63.6  32.6   8.5   0.0

SOL. AIR    O  51.7  51.0  50.1  47.1  47.2  46.2  47.5  51.1  57.6  67.6  75.2  82.5  86.1  89.0  88.0  85.1  82.3  76.8  70.3  64.2

DRY BULB    O  51.7  51.0  50.1  47.1  47.2  46.2  47.5  49.8  52.0  57.8  61.2  65.4  67.3  70.2  70.8  71.0  72.7  72.6  71.9  64.2

WET BULB    O  44.8  44.3  42.9  41.5  40.7  40.4  41.5  43.0  45.1  46.7  48.5  49.7  51.7  55.3  55.5  56.1  58.1  58.0  57.8  57.7

LONG. RAD.  O 109.4 108.9 108.1 105.8 105.6 104.8 105.6 109.0 116.3 124.2 135.2 143.3 147.7 151.1 150.4 147.4 144.2 138.5 131.7 121.9

SHORT RAD.  O 109.3 108.7 107.9 105.4 105.5 104.7 105.7 117.7 153.9 173.5 218.6 239.8 250.6 253.4 245.2 228.2 205.6 175.9 143.4 120.4

CONV.       O  -0.4  -0.8  -0.9  -2.0  -0.6  -0.9   0.3  -6.0 -31.1 -42.2 -73.8 -88.8 -97.8 -98.4 -93.7 -81.8 -63.0 -41.2 -16.9  -6.7

HEAT FLUX   O  -0.8  -0.9  -1.0  -2.4  -0.7  -1.1   0.4   2.7   6.4   7.1   9.6   7.7   5.0   4.0   1.1  -0.9  -1.6  -3.8  -5.2  -6.3

SUR. TEMP.  O  51.8  51.2  50.3  47.6  47.3  46.4  47.4  51.3  59.8  68.4  79.7  87.6  91.8  94.8  94.2  91.4  88.4  82.9  76.1  65.9

SUR. TEMP.  I  56.9  55.6  54.4  52.9  51.6  50.4  49.6  49.7  51.4  54.8  60.0  66.0  72.0  77.3  81.5  84.1  85.4  85.3  83.6  80.1

HEAT FLUX   I  -0.0  -0.0  -0.0   0.0   0.0   0.0   0.0  -0.0   0.0   0.0   0.0   0.0   0.0  -0.0   0.0   0.0   0.0  -0.0  -0.0  -0.0

CONV.       I   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0

DRY BULB    I  58.6  58.0  57.3  56.1  54.7  53.9  54.6  56.7  59.4  64.0  67.5  71.1  72.9  75.6  76.1  76.4  77.5  77.4  76.6  76.9
```

J2. Continued

```
DATA FOR 10 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON
EQUATION OF TIME =   2.540   DECLINATION =   4.911
HORIZONTAL   SURFACE TILT =   0.0   SURFACE AZIMUTH =   0.0
CLOCK TIME    21.00 22.00 23.00 24.00
SOLAR TIME     0.0   0.0   0.0   0.0
ALTITUDE        0.0   0.0   0.0   0.0
AZIMUTH         0.0   0.0   0.0   0.0
D. INTENSITY    0.0   0.0   0.0   0.0
DIRECT BEAM     0.0   0.0   0.0   0.0
SOLAR LOAD      0.0   0.0   0.0   0.0
S.H.G.F.        0.0   0.0   0.0   0.0
SOL. AIR    O  59.6  56.5  52.9  51.3
DRY BULB    O  59.6  56.5  52.9  51.3
WET BULB    O  54.2  52.5  50.0  48.2
LONG. RAD. O 117.1 114.1 111.0 109.4
SHORT RAD. O 116.2 113.4 110.3 108.9
CONV.       O  -4.2  -3.2  -3.3  -2.2
HEAT FLUX  O  -5.1  -3.6  -3.9  -2.6
SUR. TEMP. O  60.7  57.3  53.7  51.8
SUR. TEMP. I  75.8  71.6  67.5  63.8
HEAT FLUX  I   0.0   0.0   0.0   0.0
CONV.       I   0.0   0.0   0.0   0.0
DRY BULB    I  66.6  63.7  60.5  58.7
```

J2. Continued

```
DATA FOR 11 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   2.894   DECLINATION =   4.528

SOUTH WALL   SURFACE TILT =  90.00  SURFACE AZIMUTH =   0.0

CLOCK TIME      1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00 12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00

SOLAR TIME      0.0   0.0   0.0   0.0   0.0   0.0   0.0  -5.51 -4.51 -3.51 -2.51 -1.51 -0.51  0.49  1.49  2.49  3.49  4.49  5.49  0.0

ALTITUDE        0.0   0.0   0.0   0.0   0.0   0.0   0.0   8.1  16.9  25.1  32.3  37.8  40.8  40.8  37.8  32.4  25.2  17.0   8.2   0.0

AZIMUTH         0.0   0.0   0.0   0.0   0.0   0.0   0.0 -86.8 -74.4 -61.0 -46.0 -29.0 -10.0   9.8  28.8  45.8  60.8  74.2  86.6   0.0

D. INTENSITY    0.0   0.0   0.0   0.0   0.0   0.0   0.0  64.7 140.1 169.3 189.7 199.4 203.2 197.5 153.6 188.3 134.4 109.8  48.2   0.0

DIRECT BEAM     0.0   0.0   0.0   0.0   0.0   0.0   0.0   3.6  36.1  74.3 111.3 137.9 151.5 147.3 106.3 110.7  59.2  28.6   2.8   0.0

SOLAR LOAD      0.0   0.0   0.0   0.0   0.0   0.0   0.0  10.6  57.1 106.2 153.4 187.1 204.4 198.6 144.3 152.6  84.6  45.0   8.1   0.0

S.H.G.F.        0.0   0.0   0.0   0.0   0.0   0.0   0.0   5.3  31.0  72.8 114.3 142.8 157.2 152.8 110.1 113.7  58.1  24.6   4.0   0.0

SOL. AIR    O  52.1  53.6  53.0  51.7  51.8  51.5  49.6  53.8  64.5  75.5  85.3  94.5  99.8 102.2  97.2  99.0  89.9  80.8  71.5  67.8

DRY BULB    O  52.1  53.6  53.0  51.7  51.8  51.5  49.6  52.2  55.9  59.6  62.3  66.4  69.1  72.4  75.6  76.1  77.2  74.0  70.3  67.8

WET BULB    O  48.5  49.5  49.3  48.3  48.6  47.9  46.5  48.5  50.9  53.1  54.0  56.9  59.0  60.9  62.7  62.5  63.0  62.0  60.6  59.1

LONG. RAD.  O 108.5 109.7 109.4 108.4 108.3 108.1 106.6 109.2 115.3 122.1 128.3 134.8 139.0 142.1 141.2 142.3 138.3 132.3 126.0 122.7

SHORT RAD.  O 108.4 109.7 109.2 108.1 108.2 107.9 106.3 112.8 134.5 157.4 178.7 195.9 205.3 206.1 187.5 191.3 165.2 146.2 127.9 122.4

CONV.       O  -0.4   0.0  -0.7  -1.0  -0.6  -0.7  -1.3  -2.9 -16.3 -31.7 -47.0 -57.2 -63.3 -61.6 -45.7 -47.8 -28.1 -16.7  -5.3  -1.7

HEAT FLUX   O  -0.4   0.0  -0.8  -1.2  -0.7  -0.8  -1.5   0.8   2.9   3.6   3.5   3.9   3.0   2.5   0.5   1.3  -1.3  -2.8  -3.4  -2.1

SUR. TEMP.  O  52.2  53.6  53.2  51.9  51.9  51.7  49.9  52.9  60.0  67.5  74.0  80.7  84.9  87.8  87.0  88.0  84.2  78.2  71.6  68.2

SUR. TEMP.  I  58.4  59.2  59.2  58.4  58.4  58.0  56.8  58.4  61.7  65.3  68.4  71.8  74.5  77.2  79.6  80.7  81.3  79.4  76.3  73.6

HEAT FLUX   I  -0.6  -0.9  -0.6  -0.4  -0.7  -0.5  -0.3  -1.2  -1.5  -1.2  -0.6  -0.4   0.1   0.2   0.0   0.4   0.3   0.7   0.7   0.4

CONV.       I  -0.6  -0.9  -0.6  -0.4  -0.3  -0.5  -0.3  -1.2  -1.6  -1.2  -0.6  -0.4   0.1   0.2   0.0   0.4   0.3   0.7   0.7   0.4

DRY BULB    I  58.8  59.8  59.6  58.7  58.6  58.4  57.0  59.2  62.7  66.1  68.8  72.1  74.4  77.1  79.6  80.4  81.1  78.9  75.8  73.3
```

J2. Continued

```
DATA FOR 11 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   2.894   DECLINATION =   4.528

SOUTH WALL    SURFACE TILT =  90.00  SURFACE AZIMUTH =   0.0

CLOCK TIME    21.00 22.00 23.00 24.00

SOLAR TIME     0.0   0.0   0.0   0.0

ALTITUDE        0.0   0.0   0.0   0.0

AZIMUTH         0.0   0.0   0.0   0.0

D. INTENSITY    0.0   0.0   0.0   0.0

DIRECT BEAM     0.0   0.0   0.0   0.0

SOLAR LOAD      0.0   0.0   0.0   0.0

S.H.G.F.        0.0   0.0   0.0   0.0

SOL. AIR    O  59.4  59.5  57.5  52.6

DRY BULB    O  59.4  59.5  57.5  52.6

WET BULB    O  54.4  53.9  53.0  49.7

LONG. RAD. O 115.6 116.0 113.4 109.4

SHORT RAD. O 114.8 114.9 113.1 108.9

CONV.       O  -3.6  -0.8  -1.3  -2.4

HEAT FLUX   O  -4.4  -1.0  -1.5  -2.9

SUR. TEMP. O  60.3  59.7  57.8  53.2

SUR. TEMP. I  67.9  65.8  64.1  60.7

HEAT FLUX   I   1.3   0.0  -0.0   0.4

CONV.       I   1.3   0.0  -0.0   0.4

DRY BULB    I  67.0  65.8  64.1  60.4
```

J2. Continued

```
DATA FOR 11 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   2.894   DECLINATION =   4.528

WEST WALL    SURFACE TILT =  90.00  SURFACE AZIMUTH =  90.00

CLOCK TIME     1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00 12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00

SOLAR TIME     0.0   0.0   0.0   0.0   0.0   0.0   0.0  -5.51 -4.51 -3.51 -2.51 -1.51 -0.51  0.49  1.49  2.49  3.49  4.49  5.49  0.0

ALTITUDE        0.0   0.0   0.0   0.0   0.0   0.0   0.0   8.1  16.9  25.1  32.3  37.8  40.8  40.8  37.8  32.4  25.2  17.0   8.2   0.0

AZIMUTH         0.0   0.0   0.0   0.0   0.0   0.0   0.0 -86.8 -74.4 -61.0 -46.0 -29.0 -10.0   9.8  28.8  45.8  60.8  74.2  86.6   0.0

E. INTENSITY    0.0   0.0   0.0   0.0   0.0   0.0   0.0  64.7 140.1 169.3 189.7 199.4 203.2 197.5 153.6 188.3 134.4 109.8  48.2   0.0

DIRECT BEAM     0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0  25.4  58.4 114.0 106.1 101.1  47.6   0.0

SOLAR LOAD      0.0   0.0   0.0   0.0   0.0   0.0   0.0   6.2  17.6  25.8  33.1  37.9  41.2  67.8  92.5 156.2 135.6 123.6  56.4   0.0

S.H.G.F.        0.0   0.0   0.0   0.0   0.0   0.0   0.0   4.4  12.7  18.6  23.8  27.3  29.7  35.8  60.3 117.1 105.2  97.6  44.6   0.0

SOL. AIR    O  52.1  53.6  53.0  51.7  51.8  51.5  49.6  53.1  56.5  63.5  67.3  72.1  75.3  82.6  89.5  99.5  97.5  92.5  78.8  67.8

DRY BULB    O  52.1  53.6  53.0  51.7  51.8  51.5  49.6  52.2  55.9  59.6  62.3  66.4  69.1  72.4  75.6  76.1  77.2  74.0  70.3  67.8

WET BULB    O  48.5  49.5  49.3  48.3  48.6  47.9  46.5  48.5  50.9  53.1  54.0  56.9  59.0  60.9  62.7  62.5  63.0  62.0  60.6  59.1

LONG. RAD.  O 108.5 109.7 109.4 108.4 108.3 108.1 106.6 108.9 112.7 116.6 119.6 123.6 126.5 131.5 136.6 142.1 142.1 138.3 129.8 123.1

SHORT RAD.  O 108.4 109.7 109.2 108.1 108.2 107.9 106.3 111.0 118.7 125.3 130.6 136.2 140.1 153.8 166.8 192.7 185.5 177.7 147.3 122.4

CONV.       O  -0.4   0.0  -0.7  -1.0  -0.6  -0.7  -1.3  -1.5  -4.5  -7.1  -9.8 -10.8 -12.3 -19.9 -27.6 -47.4 -42.8 -40.6 -21.3  -3.0

HEAT FLUX   O  -0.4   0.0  -0.8  -1.2  -0.7  -0.8  -1.5   0.6   1.5   1.6   1.2   1.8   1.2   2.4   2.6   3.2   0.7  -1.2  -3.8  -3.7

SUR. TEMP.  O  52.2  53.6  53.2  51.9  51.9  51.7  49.9  52.6  57.0  61.4  64.7  69.1  72.2  77.4  82.5  88.0  87.9  84.1  75.6  68.8

SUR. TEMP.  I  58.4  59.2  59.2  58.4  58.4  58.0  56.8  58.4  61.6  65.0  67.9  71.1  73.7  76.4  79.1  80.5  81.4  79.7  76.6  73.7

HEAT FLUX   I  -0.6  -0.9  -0.6  -0.4  -0.7  -0.5  -0.3  -1.2  -1.7  -1.6  -1.4  -1.4  -1.1  -1.0  -0.7   0.2   0.4   1.1   1.2   0.6

CONV.       I  -0.6  -0.9  -0.6  -0.4  -0.3  -0.5  -0.3  -1.2  -1.7  -1.6  -1.4  -1.4  -1.1  -1.0  -0.7   0.2   0.4   1.1   1.2   0.6

DRY BULB    I  58.8  59.6  59.6  58.7  58.6  58.4  57.0  59.2  62.7  66.1  68.8  72.1  74.4  77.1  79.6  80.4  81.1  78.9  78.8  73.3
```

J2. Continued

```
DATA FOR 11 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   2.894   DECLINATION =   4.528

WEST WALL    SURFACE TILT =  90.00  SURFACE AZIMUTH =  90.00

CLOCK TIME   21.00 22.00 23.00 24.00

SOLAR TIME    0.0   0.0   0.0   0.0

ALTITUDE       0.0   0.0   0.0   0.0

AZIMUTH        0.0   0.0   0.0   0.0

D. INTENSITY   0.0   0.0   0.0   0.0

DIRECT BEAM    0.0   0.0   0.0   0.0

SOLAR LOAD     0.0   0.0   0.0   0.0

S.H.G.F.       0.0   0.0   0.0   0.0

SOL. AIR    O  59.4  59.5  57.5  52.6

DRY BULB    O  59.4  59.5  57.5  52.6

WET BULB    O  54.4  53.9  53.0  49.7

LONG. RAD. O 115.6 115.0 113.4 109.4

SHORT RAD. O 114.8 114.9 113.1 108.9

CONV.       O  -3.7  -0.8  -1.3  -2.4

HEAT FLUX  O  -4.5  -1.0  -1.5  -2.9

SUR. TEMP. O  60.3  59.7  57.8  53.2

SUR. TEMP. I  67.9  65.8  64.1  60.7

HEAT FLUX  I   1.3   0.0  -0.0   0.4

CONV.       I   1.3   0.0  -0.0   0.4

DRY BULB    I  67.0  65.8  64.1  60.4
```

J2. Continued

```
DATA FOR 11 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   2.894   DECLINATION =   4.528

EAST WALL    SURFACE TILT =  90.00  SURFACE AZIMUTH = -90.00

CLOCK TIME     1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00 12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00

SOLAR TIME     0.0   0.0   0.0   0.0   0.0   0.0   0.0  -5.51 -4.51 -3.51 -2.51 -1.51 -0.51  0.49  1.49  2.49  3.49  4.49  5.49  0.0

ALTITUDE        0.0   0.0   0.0   0.0   0.0   0.0   0.0   8.1  16.9  25.1  32.3  37.8  40.8  40.8  37.8  32.4  25.2  17.0   8.2   0.0

AZIMUTH         0.0   0.0   0.0   0.0   0.0   0.0   0.0 -86.8 -74.4 -61.0 -46.C -29.0 -10.0   9.8  28.8  45.8  60.8  74.2  86.6   0.0

D. INTENSITY    0.0   0.0   0.0   0.0   0.0   0.0   0.0  64.7 140.1 169.3 189.7 199.4 203.2 197.5 153.6 188.3 134.4 109.8  48.2   0.0

DIRECT BEAM     0.0   0.0   0.0   0.0   0.0   0.0   0.0  63.9 129.2 134.1 115.3  76.4  26.7   0.0   0.0   0.0   0.0   0.0   0.0   0.0

SOLAR LOAD      0.0   0.0   0.0   0.0   0.0   0.0   0.0  75.7 157.9 171.1 157.9 120.7  70.4  40.1  29.2  32.9  20.5  13.8   4.6   0.0

S.H.G.F.        0.0   0.0   0.0   0.0   0.0   0.0   0.0  59.9 124.6 132.8 118.4  78.9  37.1  28.9  21.0  23.7  14.8   9.9   3.3   0.0

SOL. AIR    O  52.1  53.6  53.0  51.7  51.8  51.5  49.6  63.6  79.6  85.3  86.0  84.5  79.7  78.4  80.0  81.0  80.3  76.1  71.0  67.8

DRY BULB    O  52.1  53.6  53.0  51.7  51.8  51.5  49.6  52.2  55.9  59.6  62.3  66.4  69.1  72.4  75.6  76.1  77.2  74.0  70.3  67.8

WET BULB    O  48.5  49.5  49.3  48.3  48.6  47.9  46.5  48.5  50.9  53.1  54.0  56.9  59.0  60.9  62.7  62.5  63.0  62.0  60.6  59.1

LONG. RAD.  O 108.5 109.7 109.4 108.4 108.3 108.1 106.6 113.3 122.3 127.1 129.0 130.1 129.0 129.7 131.9 132.7 133.0 129.6 125.8 122.7

SHORT RAD.  O 108.4 109.7 109.2 108.1 108.2 107.9 106.3 138.8 174.9 183.4 180.5 169.4 151.7 142.7 141.4 143.4 139.5 133.7 126.5 122.4

CONV.       O  -0.4   0.0  -0.7  -1.0  -0.6  -0.7  -1.3 -22.2 -47.5 -53.2 -49.9 -38.2 -23.0 -12.7  -8.6 -10.4  -6.6  -6.0  -3.5  -1.6

HEAT FLUX   O  -0.4   0.0  -0.8  -1.2  -0.7  -0.8  -1.5   3.3   5.0   3.1   1.6   1.1  -0.3   0.3   0.9   0.3  -0.1  -1.9  -2.5  -1.9

SUR. TEMP.  O  52.2  53.6  53.2  51.9  51.9  51.7  49.9  57.8  67.8  72.9  74.8  75.9  74.9  75.6  77.8  78.7  78.9  75.8  71.2  68.2

SUR. TEMP.  I  58.4  59.2  59.2  58.4  58.4  58.0  56.8  58.6  62.1  65.7  68.6  71.7  74.0  76.5  78.9  80.0  80.8  79.1  76.2  73.8

HEAT FLUX   I  -0.6  -0.9  -0.6  -0.4  -0.7  -0.5  -0.3  -0.9  -0.9  -0.6  -0.3  -0.6  -0.6  -0.9  -1.0  -0.5  -0.5   0.3   0.5   0.4

CONV.       I  -0.6  -0.9  -0.6  -0.4  -0.3  -0.5  -0.3  -0.9  -0.9  -0.6  -0.3  -0.6  -0.6  -0.9  -1.0  -0.5  -0.5   0.3   0.5   0.4

DRY BULB    I  58.8  59.8  59.6  58.7  58.6  58.4  57.0  59.2  62.7  66.1  68.8  72.1  74.4  77.1  79.6  80.4  81.1  78.9  76.8  73.3
```

J2. Continued

```
DATA FOR 11 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   2.894   DECLINATION =   4.528

EAST WALL     SURFACE TILT =  90.00  SURFACE AZIMUTH = -90.00

CLOCK TIME    21.00 22.00 23.00 24.00

SOLAR TIME     0.0   0.0   0.0   0.0

ALTITUDE        0.0   0.0   0.0   0.0

AZIMUTH         0.0   0.0   0.0   0.0

D. INTENSITY    0.0   0.0   0.0   0.0

DIRECT BEAM     0.0   0.0   0.0   0.0

SOLAR LOAD      0.0   0.0   0.0   0.0

S.H.G.F.        0.0   0.0   0.0   0.0

SOL. AIR    O  59.4  59.5  57.5  52.6

DRY BULB    O  59.4  59.5  57.5  52.6

WET BULB    O  54.4  53.9  53.0  49.7

LONG. RAD. O 115.6 115.0 113.4 109.4

SHORT RAD. O 114.8 114.9 113.1 108.9

CONV.       O  -3.6  -0.8  -1.3  -2.4

HEAT FLUX   O  -4.4  -1.0  -1.5  -2.9

SUR. TEMP. O  60.3  59.7  57.8  53.2

SUR. TEMP. I  67.9  65.8  64.1  60.7

HEAT FLUX   I   1.3   0.0  -0.0   0.4

CONV.       I   1.3   0.0  -0.0   0.4

DRY BULB    I  67.9  65.8  64.1  60.4
```

J2. Continued

```
DATA FOR 11 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.   LOCATION   EDMONTON

EQUATION OF TIME =   2.894   DECLINATION =   4.528

NORTH WALL   SURFACE TILT =  90.00  SURFACE AZIMUTH = 180.00

CLOCK TIME     1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00 12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00

SOLAR TIME     0.0   0.0   0.0   0.0   0.0   0.0   0.0  -5.51 -4.51 -3.51 -2.51 -1.51 -0.51  0.49  1.49  2.49  3.49  4.49  5.49  0.0

ALTITUDE        0.0   0.0   0.0   0.0   0.0   0.0   0.0   8.1  16.9  25.1  32.3  37.8  40.5  40.8  37.6  32.4  25.2  17.0   8.2   0.0

AZIMUTH         0.0   0.0   0.0   0.0   0.0   0.0   0.0 -86.8 -74.4 -61.0 -46.C -29.0 -10.0   9.8  28.6  45.8  60.8  74.2  86.6   0.0

D. INTENSITY   0.0   0.0   0.0   0.0

DIRECT BEAM     0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0

SOLAR LOAD      0.0   0.0   0.0   0.0   0.0   0.0   0.0   6.7  17.6  25.8  33.1  37.9  40.2  39.1  29.2  32.9  20.5  13.8   5.0   0.0

S.H.G.F.        0.0   0.0   0.0   0.0   0.0   0.0   0.0   4.8  12.7  18.6  23.8  27.3  29.0  28.2  21.0  23.7  14.8   9.9   3.6   0.0

SOL. AIR    O  52.1  53.6  53.0  51.7  51.8  51.5  49.6  53.2  58.5  63.5  67.3  72.1  75.1  78.3  80.0  81.0  80.3  76.1  71.0  67.8

DRY BULB    O  52.1  53.6  53.0  51.7  51.8  51.5  49.6  52.2  55.9  59.6  62.3  66.4  69.1  72.4  75.6  76.1  77.2  74.0  70.3  67.8

WET BULB    O  48.5  49.5  49.3  48.3  48.6  47.9  46.5  48.5  50.9  53.1  54.0  56.9  59.0  60.9  62.7  62.5  63.0  62.0  60.6  59.1

LONG. RAD. O 108.5 109.7 109.4 108.4 108.3 108.1 106.6 108.9 112.7 116.6 119.6 123.6 126.4 129.5 131.9 132.7 133.0 129.6 125.5 122.7

SHORT RAD. O 108.4 109.7 109.2 108.1 108.2 107.9 106.3 111.2 118.7 125.3 130.6 136.2 139.7 142.3 141.4 143.4 139.5 133.7 126.7 122.4

CONV.       O  -0.4   0.0  -0.7  -1.0  -0.6  -0.7  -1.3  -1.7  -4.5  -7.1  -9.8 -10.8 -12.0 -11.5  -8.6 -10.4  -6.6  -6.0  -3.6  -1.4

HEAT FLUX   O  -0.4   0.0  -0.8  -1.2  -0.7  -0.8  -1.5   0.6   1.5   1.6   1.2   1.8   1.2   1.3   1.0   0.3  -0.1  -1.9  -2.5  -1.9

SUR. TEMP. O  52.2  53.6  53.2  51.9  51.9  51.7  49.9  52.6  57.0  61.4  64.7  69.1  72.1  75.3  77.7  78.7  78.9  75.5  71.2  68.2

SUR. TEMP. I  58.4  59.2  59.2  58.4  58.4  58.0  56.8  58.4  61.6  65.0  67.9  71.1  73.7  76.4  78.9  80.0  80.8  79.1  76.2  73.6

HEAT FLUX   I  -0.6  -0.9  -0.6  -0.4  -0.7  -0.5  -0.3  -1.2  -1.7  -1.6  -1.4  -1.4  -1.1  -1.1  -1.0  -0.5  -0.5   0.3   0.5   0.4

CONV.       I  -0.6  -0.9  -0.6  -0.4  -0.3  -0.5  -0.3  -1.2  -1.7  -1.6  -1.4  -1.4  -1.1  -1.1  -1.0  -0.5  -0.5   0.3   0.5   0.4

DRY BULB    I  58.8  59.8  59.6  58.7  58.6  58.4  57.0  59.2  62.7  66.1  68.8  72.1  74.4  77.1  79.6  80.4  81.1  78.9  75.8  73.3
```

J2. Continued

```
DATA FOR 11 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   2.894   DECLINATION =    4.528

NORTH WALL   SURFACE TILT =  90.00  SURFACE AZIMUTH = 180.00

CLOCK TIME   21.00 22.00 23.00 24.00

SOLAR TIME    0.0   0.0   0.0   0.0

ALTITUDE       0.0   0.0   0.0   0.0

AZIMUTH        0.0   0.0   0.0   0.0

D. INTENSITY   0.0   0.0   0.0   0.0

DIRECT BEAM    0.0   0.0   0.0   0.0

SOLAR LOAD     0.0   0.0   0.0   0.0

S.H.G.F.       0.0   0.0   0.0   0.0

SOL. AIR   O  59.4  59.5  57.5  52.6

DRY BULB   O  59.4  59.5  57.5  52.6

WET BULB   O  54.4  53.9  53.0  49.7

LONG. RAD. O 115.6 115.0 113.4 109.4

SHORT RAD. O 114.8 114.9 113.1 108.9

CONV.      O  -3.6  -0.8  -1.3  -2.4

HEAT FLUX  O  -4.4  -1.0  -1.5  -2.9

SUR. TEMP. O  60.3  59.7  57.8  53.2

SUR. TEMP. I  67.9  65.8  64.1  60.7

HEAT FLUX  I   1.3   0.0  -0.0   0.4

CONV.      I   1.3   0.0  -0.0   0.4

DRY BULB   I  67.9  65.8  64.1  60.4
```

J2. Continued

```
DATA FOR 11 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   2.894   DECLINATION =   4.528

WEST SLOPE   SURFACE TILT =  20.50  SURFACE AZIMUTH =  90.00

CLOCK TIME     1.00   2.00   3.00   4.00   5.00   6.00   7.00   8.00   9.00  10.00  11.00  12.00  13.00  14.00  15.00  16.00  17.00  18.00  19.00  20.00

SOLAR TIME     0.0    0.0    0.0    0.0    0.0    0.0    0.0   -5.51  -4.51  -3.51  -2.51  -1.51  -0.51   0.49   1.49   2.49   3.49   4.49   5.49   0.0

ALTITUDE        0.0    0.0    0.0    0.0    0.0    0.0    0.0    8.1   16.9   25.1   32.3   37.8   40.8   40.8   37.8   32.4   25.2   17.0    8.2    0.0

AZIMUTH         0.0    0.0    0.0    0.0    0.0    0.0    0.0  -86.8  -74.4  -61.0  -46.C  -29.0  -10.0    9.8   28.8   45.8   60.8   74.2   86.6    0.0

D. INTENSITY    0.0    0.0    0.0    0.0    0.0    0.0    0.0   64.7  140.1  169.3  189.7  199.4  203.2  197.5  153.6  188.3  134.4  109.8   48.2    0.0

DIRECT BEAM     0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0   20.4   54.7   87.7  115.0  129.8  108.7  134.5   90.8   65.4   23.1    0.0

SOLAR LOAD      0.0    0.0    0.0    0.0    0.0    0.0    0.0    6.6   14.4   38.0   74.4  108.6  136.4  150.5  124.8  154.1  104.8   76.7   28.0    0.0

S.H.G.F.        0.0    0.0    0.0    0.0    0.0    0.0    0.0    4.7   10.4   16.6   41.0   73.9  101.2  115.2   96.5  119.3   80.5   57.7   19.7    0.0

SOL. AIR    O  52.1   53.6   53.0   51.7   51.8   51.5   49.6   51.3   54.8   62.5   69.7   78.5   85.3   92.2   93.4   95.9   92.0   84.6   74.0   67.8

DRY BULB    O  52.1   53.6   53.0   51.7   51.8   51.5   49.6   52.2   55.9   59.6   62.3   66.4   69.1   72.4   75.6   76.1   77.2   74.0   70.3   67.8

WET BULB    O  48.5   49.5   49.3   48.3   48.6   47.9   46.5   48.5   50.9   53.1   54.0   56.9   59.0   60.9   62.7   62.5   63.0   62.0   60.6   59.1

LONG. RAD. O  109.7  110.9  110.6  109.6  109.5  109.3  107.8  110.4  114.6  121.1  129.0  138.4  146.0  152.1  151.9  156.9  150.9  143.1  132.0  124.7

SHORT RAD. O  109.6  110.9  110.4  109.3  109.4  109.1  107.5  115.1  124.7  147.3  179.7  211.5  236.7  251.5  233.5  258.0  218.6  192.5  149.0  123.7

CONV.       O  -0.3    0.3   -0.7   -1.2   -0.6   -0.7   -1.5   -3.2   -7.4  -21.5  -44.5  -65.7  -84.3  -93.7  -80.0  -96.2  -69.9  -53.4  -24.3   -4.4

HEAT FLUX   O  -0.4    0.3   -0.9   -1.5   -0.7   -0.8   -1.8    1.5    2.8    4.8    6.1    7.3    6.4    5.7    1.5    4.9   -2.2   -4.0   -7.3   -5.4

SUR. TEMP.  O  52.2   53.5   53.2   52.0   51.9   51.7   50.0   53.0   57.7   65.0   73.4   82.8   90.2   95.8   95.6  100.1   94.7   87.4   76.4   68.9

SUR. TEMP.  I  58.4   59.2   59.2   58.5   58.2   58.0   56.8   58.5   61.7   65.2   68.3   71.9   74.7   77.5   80.1   81.3   81.9   79.9   76.7   73.8

HEAT FLUX   I  -0.6   -0.9   -0.6   -0.4   -0.6   -0.6   -0.3   -1.2   -1.6   -1.4   -0.8   -0.4    0.4    0.7    0.8    1.4    1.3    1.7    1.4    0.7

CONV.       I  -0.6   -0.9   -0.6   -0.4   -0.6   -0.6   -0.3   -1.2   -1.6   -1.4   -0.8   -0.4    0.4    0.7    0.8    1.4    1.3    1.7    1.4    0.7

DRY BULB    I  58.8   59.8   59.6   58.7   58.6   58.4   57.0   59.2   62.7   66.1   68.8   72.1   74.4   77.1   79.6   80.4   81.1   78.9   78.8   73.3
```

J2. Continued

```
DATA FOR 11 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   2.894   DECLINATION =   4.528

WEST SLOPE   SURFACE TILT =  20.50  SURFACE AZIMUTH =  90.00

CLOCK TIME   21.00 22.00 23.00 24.00

SOLAR TIME    0.0   0.0   0.0   0.0

ALTITUDE       0.0   0.0   0.0   0.0

AZIMUTH        0.0   0.0   0.0   0.0

D. INTENSITY   0.0   0.0   0.0   0.0

DIRECT BEAM    0.0   0.0   0.0   0.0

SOLAR LOAD     0.0   0.0   0.0   0.0

S.H.G.F.       0.0   0.0   0.0   0.0

SOL. AIR    O  59.4  59.5  57.5  52.6

DRY BULB    O  59.4  59.5  57.5  52.6

WET BULB    O  54.4  53.9  53.0  49.7

LONG. RAD. O 117.2 116.4 114.7 110.7

SHORT RAD. O 116.0 116.1 114.3 110.1

CONV.       O  -5.1  -1.0  -1.6  -3.1

HEAT FLUX   O  -6.3  -1.3  -1.9  -3.8

SUR. TEMP. O  60.7  59.8  57.9  53.4

SUR. TEMP. I  67.9  65.9  64.1  60.7

HEAT FLUX   I   1.5   0.1   0.0   0.5

CONV.       I   1.5   0.1   0.0   0.5

DRY BULB    I  67.8  65.8  64.1  60.4
```

J2. Continued

```
DATA FOR 11 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   2.894   DECLINATION =   4.528

EAST SLOPE   SURFACE TILT =  20.50  SURFACE AZIMUTH = -90.00

CLOCK TIME     1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00 12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00

SOLAR TIME     0.0   0.0   0.0   0.0   0.0   0.0   0.0  -5.51 -4.51 -3.51 -2.51 -1.51 -0.51  0.49  1.49  2.49  3.49  4.49  5.49  0.0

ALTITUDE        0.0   0.0   0.0   0.0   0.0   0.0   0.0   8.1  16.9  25.1  32.3  37.8  40.8  40.8  37.8  32.4  25.2  17.0   8.2   0.0

AZIMUTH         0.0.  0.0   0.0   0.0   0.0   0.0   0.0 -86.8 -74.4 -61.0 -46.0 -29.0 -10.0   9.8  28.8  45.8  60.8  74.2  86.6   0.0

D. INTENSITY    0.0   0.0   0.0   0.0   0.0   0.0   0.0  84.7 140.1 169.3 189.7 199.4 203.2 197.5 153.6 168.3 134.4 109.8  48.2   0.0

DIRECT BEAM     0.0   0.0   0.0   0.0   0.0   0.0   0.0  30.9  83.3 114.3 135.5 141.2 133.7 112.0  67.8  54.6  16.5   0.0   0.0   0.0

SOLAR LOAD      0.0   0.0   0.0   0.0   0.0   0.0   0.0  37.5  97.7 131.9 155.2 162.1 155.1 132.7  83.9  74.2  30.4  11.3   4.9   0.0

S.H.G.F.        0.0   0.0   0.0   0.0   0.0   0.0   0.0  26.4  73.4 101.3 120.2 125.4 118.7  98.6  57.2  41.0  13.3   8.1   3.8   0.0

SOL. AIR    O  52.1  53.6  53.0  51.7  51.8  51.5  49.6  55.9  67.3  76.6  81.8  86.5  88.1  89.5  87.3  84.0  80.8  74.8  70.6  67.8

DRY BULB    O  52.1  53.6  53.0  51.7  51.8  51.5  49.6  52.2  55.9  59.6  62.3  66.4  69.1  72.4  75.6  76.1  77.2  74.0  70.3  67.8

WET BULB    O  48.5  49.5  49.3  48.3  48.6  47.9  46.5  48.5  50.9  53.1  54.0  56.9  59.0  60.9  62.7  62.5  63.0  62.0  60.6  59.1

LONG. RAD. O 109.7 110.9 110.6 109.6 109.5 109.3 107.8 114.3 126.1 135.4 142.3 147.9 150.0 149.9 145.5 144.0 138.4 132.3 127.5 124.2

SHORT RAD. O 109.6 110.9 110.4 109.3 109.4 109.1 107.5 140.4 193.1 224.3 245.9 255.3 252.1 236.9 200.0 192.5 157.7 138.9 130.1 123.7

CONV.       O  -0.3   0.3  -0.7  -1.2  -0.6  -0.7  -1.5 -21.3 -57.7 -81.2 -97.3-102.0 -98.8 -85.3 -56.1 -48.6 -22.6 -10.9  -6.3  -2.4

HEAT FLUX   O  -0.4   0.3  -0.9  -1.5  -0.7  -0.8  -1.8   4.8   9.3   7.8   6.3   5.5   3.3   1.7  -1.6  -0.1  -3.3  -4.3  -3.7  -2.9

SUR. TEMP. O  52.2  53.5  53.2  52.0  51.9  51.7  50.0  57.5  70.3  79.9  86.6  91.9  93.8  93.7  89.6 [illegible] 82.8  76.7  71.9  68.4

SUR. TEMP. I  58.4  59.2  59.2  58.5  58.2  58.0  56.8  58.6  62.2  66.0  69.1  72.5  75.0  77.6  79.9  80.7  81.2  79.3  76.2  73.6

HEAT FLUX   I  -0.6  -0.9  -0.6  -0.4  -0.6  -0.6  -0.3  -1.0  -0.8  -0.2   0.5   0.7   1.0   0.8   0.4   0.5   0.2   0.6   0.7   0.5

CONV.       I  -0.6  -0.9  -0.6  -0.4  -0.6  -0.6  -0.3  -1.0  -0.8  -0.2   0.5   0.7   1.0   0.8   0.4   0.5   0.2   0.6   0.7   0.5

DRY BULB    I  58.8  59.8  59.6  58.7  58.6  58.4  57.0  59.2  62.7  66.1  68.8  72.1  74.4  77.1  79.6  80.4  81.1  78.9  75.8  73.3
```

J2. Continued

```
DATA FOR 11 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   2.894   DECLINATION =   4.528

EAST SLOPE   SURFACE TILT =  20.50  SURFACE AZIMUTH = -90.00

CLOCK TIME    21.00 22.00 23.00 24.00

SOLAR TIME     0.0   0.0   0.0   0.0

ALTITUDE        0.0   0.0   0.0   0.0

AZIMUTH         0.0   0.0   0.0   0.0

D. INTENSITY    0.0   0.0   0.0   0.0

DIRECT BEAM     0.0   0.0   0.0   0.0

SOLAR LOAD      0.0   0.0   0.0   0.0

S.H.G.F.        0.0   0.0   0.0   0.0

SOL. AIR    O  59.4  59.5  57.5  52.6

DRY BULB    O  59.4  59.5  57.5  52.6

WET BULB    O  54.4  53.9  53.0  49.7

LONG. RAD. O 117.1 116.4 114.7 110.7

SHORT RAD. O 116.0 116.1 114.3 110.1

CONV.       O  -4.9  -1.0  -1.6  -3.1

HEAT FLUX   O  -6.0  -1.3  -1.9  -3.8

SUR. TEMP. O  60.6  59.8  57.9  53.4

SUR. TEMP. I  67.9  65.8  64.1  60.7

HEAT FLUX   I   1.4   0.1   0.0   0.5

CONV.       I   1.4   0.1   0.0   0.5

DRY BULB    I  67.0  65.8  64.1  60.4
```

J2. Continued

```
DATA FOR 11 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   2.894   DECLINATION =   4.528

HORIZONTAL   SURFACE TILT =   0.0   SURFACE AZIMUTH =   0.0

CLOCK TIME      1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00 12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00

SOLAR TIME      0.0   0.0   0.0   0.0   0.0   0.0   0.0  -5.51 -4.51 -3.51 -2.51 -1.51 -0.51  0.49  1.49  2.49  3.49  4.49  5.49  0.0

ALTITUDE         0.0   0.0   0.0   0.0   0.0   0.0   0.0   8.1  16.9  25.1  32.3  37.8  40.8  40.8  37.8  32.4  25.2  17.0   8.2   0.0

AZIMUTH          0.0   0.0   0.0   0.0   0.0   0.0   0.0 -86.8 -74.4 -61.0 -46.0 -29.0 -10.0   9.8  28.8  45.8  60.8  74.2  89.6   0.0

D. INTENSITY     0.0   0.0   0.0   0.0   0.0   0.0   0.0  64.7 140.1 169.3 189.7 199.4 203.2 197.5 153.6 168.3 134.4 109.8  48.2   0.0

DIRECT BEAM      0.0   0.0   0.0   0.0   0.0   0.0   0.0   9.1  40.7  71.9 101.5 122.2 132.8 129.0  94.2 100.9  57.3  32.1   6.8   0.0

SOLAR LOAD       0.0   0.0   0.0   0.0   0.0   0.0   0.0  15.8  55.2  89.5 121.1 142.9 153.8 149.5 110.1 120.4  71.2  43.4  11.8   0.0

S.H.G.F.         0.0   0.0   0.0   0.0   0.0   0.0   0.0   6.9  30.5  60.0  88.6 108.0 117.6 114.3  83.3  88.1  47.8  24.1   8.2   0.0

SOL. AIR    O  52.1  53.6  53.0  51.7  51.8  51.5  49.6  52.6  60.7  70.0  76.5  83.3  87.7  91.8  91.1  90.7  86.9  79.5  71.6  67.8

DRY BULB    O  52.1  53.6  53.0  51.7  51.8  51.5  49.6  52.2  55.9  59.6  62.3  66.4  69.1  72.4  75.6  76.1  77.2  74.0  70.3  67.8

WET BULB    O  48.5  49.5  49.3  48.3  48.6  47.9  46.5  48.5  50.9  53.1  54.0  56.9  59.0  60.9  62.7  62.5  63.0  62.0  60.6  59.1

LONG. RAD. O 109.7 110.9 110.5 109.5 109.5 109.2 107.8 111.5 119.9 128.6 136.4 144.2 149.3 152.4 149.7 151.6 145.4 137.8 129.3 124.5

SHORT RAD. O 109.6 110.9 110.4 109.3 109.4 109.1 107.5 122.6 158.2 169.6 217.9 239.6 251.1 250.7 221.5 230.4 191.1 165.2 135.8 123.7

CONV.       O  -0.6   0.2  -0.6  -1.0  -0.4  -0.5  -1.3  -8.2 -31.2 -53.4 -74.3 -88.2 -96.5 -94.5 -72.1 -76.7 -49.2 -32.7 -13.2  -3.7

HEAT FLUX   O  -0.8   0.2  -0.6  -1.3  -0.4  -0.5  -1.5   2.9   7.1   7.6   7.2   7.2   5.3   3.8  -0.3   2.2  -3.5  -5.2  -6.8  -4.6

SUR. TEMP. O  52.3  53.6  53.2  52.0  51.9  51.6  49.9  54.3  63.7  72.9  80.9  88.4  93.2  96.0  93.6  95.3  89.5  82.2  73.6  68.7

SUR. TEMP. I  61.0  59.1  57.6  56.4  55.3  54.4  53.4  53.3  55.0  58.6  63.4  68.9  74.4  79.5  83.1  86.0  87.3  86.7  84.2  80.8

HEAT FLUX   I   0.0  -0.0  -0.0  -0.0  -0.0   0.0   0.0  -0.0   0.0   0.0   0.0   0.0   0.0  -0.0   0.0  -0.0  -0.0  -0.0  -0.0   0.0

CONV.       I   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0

DRY BULB    I  60.8  59.8  59.6  58.7  58.6  58.4  57.9  59.2  62.7  64.1  68.8  72.1  74.4  77.1  79.6  80.4  81.1  78.9  75.8  73.3
```

J2. Continued

```
DATA FOR 11 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   2.694   DECLINATION =   4.528

HORIZONTAL   SURFACE TILT =   0.0   SURFACE AZIMUTH =   0.0

CLOCK TIME     21.00 22.00 23.00 24.00

SOLAR TIME      0.0   0.0   0.0   0.0

ALTITUDE         0.0   0.0   0.0   .0.0

AZIMUTH          0.0   0.0   0.0   0.0

D. INTENSITY     0.0   0.0   0.0   0.0

DIRECT BEAM      0.0   0.0   0.0   0.0

SOLAR LOAD       0.0   0.0   0.0   0.0

S.H.G.F.         0.0   0.0   0.0   0.0

SOL. AIR    O  59.4  59.5  57.5  52.6

DRY BULB    O  59.4  59.5  57.5  52.6

WET BULB    O  54.4  53.9  53.0  49.7

LONG. RAD. O 117.3 116.5 114.8 110.8

SHORT RAD. O 116.0 116.1 114.3 110.1

CONV.       O  -5.7  -1.7  -2.1  -3.6

HEAT FLUX   O  -7.0  -2.1  -2.5  -4.4

SUR. TEMP. O  60.8  59.9  58.0  53.5

SUR. TEMP. I  76.6  72.6  69.2  65.7

HEAT FLUX   I  -0.0  -0.0   0.0   0.0

CONV.       I   0.0   0.0   0.0   0.0

DRY BULB    I  67.0  65.8  64.1  60.4
```

J2. Continued

```
DATA FOR 12 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   3.250   DECLINATION =   4.144

SOUTH WALL   SURFACE TILT =  90.00  SURFACE AZIMUTH =   0.0

CLOCK TIME     1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00 12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00

SOLAR TIME    0.0   0.0   0.0   0.0   0.0   0.0   0.0  -5.50 -4.50 -3.50 -2.50 -1.50 -0.50  0.50  1.50  2.50  3.50  4.50  5.50  0.0

ALTITUDE        0.0   0.0   0.0   0.0   0.0   0.0   0.0   7.8  16.6  24.9  32.0  37.5  40.4  40.4  37.5  32.0  24.9  16.6   7.8   0.0

AZIMUTH         0.0   0.0   0.0   0.0   0.0   0.0   0.0 -86.5 -74.1 -60.7 -45.7 -28.7  -9.8   9.8  28.7  45.7  60.7  74.1  86.5   0.0

D. INTENSITY    0.0   0.0   0.0   0.0   0.0   0.0   0.0  52.8  74.5  91.7 100.5 105.1 107.2 107.2 105.1 100.5  91.7  74.5  36.2   0.0

DIRECT BEAM     0.0   0.0   0.0   0.0   0.0   0.0   0.0   3.2  19.6  40.7  59.5  73.2  80.4  80.4  73.2  59.5  40.7  19.6   2.2   0.0

SOLAR LOAD      0.0   0.0   0.0   0.0   0.0   0.0   0.0   8.9  30.6  57.9  81.7  99.0 108.1 108.1  99.0  81.7  57.9  30.6   6.1   0.0

S.H.G.F.        0.0   0.0   0.0   0.0   0.0   0.0   0.0   4.4  16.8  39.8  60.9  75.6  83.2  83.2  75.6  60.9  39.8  16.8   3.0   0.0

SOL. AIR    O  51.8  51.7  50.4  49.9  50.3  49.0  48.7  50.4  55.0  59.3  60.3  59.1  60.6  59.5  57.2  51.3  47.7  41.9  36.3  33.3

DRY BULB    O  51.8  51.7  50.4  49.9  50.3  49.0  48.7  49.1  50.4  50.6  48.0  44.3  44.4  43.3  42.4  39.0  39.0  37.3  35.4  33.3

WET BULB    O  48.8  48.8  47.7  47.2  47.6  46.0  45.3  45.2  46.6  46.6  43.9  39.9  40.8  40.1  39.4  35.5  35.6  33.9  31.6  29.3

LONG. RAD.  O 108.4 108.2 107.3 106.8 107.0 106.1 105.8 106.6 109.0 111.1 110.8 109.0 109.5 108.7 107.3 103.6 101.8  98.8  95.8  93.7

SHORT RAD.  O 108.2 108.1 107.0 106.6 106.9 105.8 105.6 109.5 119.3 130.3 137.7 141.6 145.3 144.4 140.1 130.4 120.9 108.7  97.4  93.4

CONV.       O  -1.0  -0.7  -1.0  -0.8  -0.5  -1.0  -0.7  -3.2  -9.5 -18.5 -27.3 -33.8 -35.7 -36.2 -33.5 -29.2 -20.5 -12.2  -4.3  -2.0

HEAT FLUX   O  -1.3  -0.8  -1.3  -1.0  -0.5  -1.3  -0.9  -0.2   0.8   0.8  -0.4  -1.2   0.2  -0.5  -0.8  -2.3  -1.4  -2.4  -2.6  -2.4

SUR. TEMP.  O  52.1  51.9  50.7  50.1  50.4  49.3  48.9  49.9  52.8  55.2  54.8  52.7  53.3  52.4  50.8  46.3  44.1  40.4  36.5  33.8

SUR. TEMP.  I  59.0  58.4  57.4  56.8  56.8  56.1  55.6  56.2  57.3  58.1  57.0  54.5  53.7  52.7  51.8  49.5  48.5  46.9  45.1  45.5

HEAT FLUX   I  -0.2  -0.5  -0.4  -0.5  -0.7  -0.5  -0.6  -0.9  -1.0  -0.6   0.1   0.7   0.2   0.3   0.2   0.6  -0.1  -0.1  -0.2  -1.3

CONV.       I  -0.2  -0.5  -0.4  -0.5  -0.7  -0.5  -0.6  -0.9  -1.0  -0.6   0.1   0.7   0.2   0.3   0.2   0.6  -0.1  -0.1  -0.2  -1.3

DRY BULB    I  59.1  58.7  57.7  57.2  57.3  56.4  56.0  56.8  56.8  56.5  56.9  54.1  53.5  52.8  51.7  49.1  48.5  47.0  46.2  46.4
```

J2. Continued

```
DATA FOR 12 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   3.250   DECLINATION =   4.144

SOUTH WALL    SURFACE TILT =  90.00  SURFACE AZIMUTH =   0.0

CLOCK TIME     21.00 22.00 23.00 24.00

SOLAR TIME      0.0   0.0   0.0   0.0

ALTITUDE         0.0   0.0   0.0   0.0

AZIMUTH          0.0   0.0   0.0   0.0

D. INTENSITY     0.0   0.0   0.0   0.0

DIRECT BEAM      0.0   0.0   0.0   0.0

SOLAR LOAD       0.0   0.0   0.0   0.0

S.H.G.F.         0.0   0.0   0.0   0.0

SOL. AIR    O  33.7  33.8  33.8  33.7

DRY BULB    O  33.7  33.8  33.8  33.7

WET BULB    O  30.1  29.9  30.1  30.1

LONG. RAD. O  93.9  94.0  94.0  93.9

SHORT RAD. O  93.7  93.8  93.8  93.7

CONV.       O  -1.0  -1.0  -1.1  -1.2

HEAT FLUX  O  -1.2  -1.2  -1.3  -1.4

SUR. TEMP. O  33.9  34.1  34.1  34.0

SUR. TEMP. I  45.8  46.4  46.4  46.6

HEAT FLUX  I  -1.4  -1.5  -1.3  -1.4

CONV.       I  -1.3  -1.5  -2.0  -1.4

DRY BULB    I  46.7  47.5  47.8  47.6
```

J2. Continued

```
DATA FOR 12 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON
EQUATION OF TIME =    3.250   DECLINATION =    4.144
WEST WALL     SURFACE TILT =  90.00  SURFACE AZIMUTH =  90.00
CLOCK TIME      1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00 12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00
SOLAR TIME      0.0   0.0   0.0   0.0   0.0   0.0   0.0  -5.50 -4.50 -3.50 -2.50 -1.50 -0.50  0.50  1.50  2.50  3.50  4.50  5.50  0.0
ALTITUDE        0.0   0.0   0.0   0.0   0.0   0.0   0.0   7.8  16.6  24.9  32.0  37.5  40.4  40.4  37.5  32.0  24.9  16.6   7.8   0.0
AZIMUTH         0.0   0.0   0.0   0.0   0.0   0.0   0.0 -86.5 -74.1 -60.7 -45.7 -28.7  -9.8   9.8  28.7  45.7  60.7  74.1  86.5   0.0
D. INTENSITY    0.0   0.0   0.0   0.0   0.0   0.0   0.0  52.8  74.5  91.7 100.5 105.1 107.2 107.2 105.1 100.5  91.7  74.5  36.2   0.0
DIRECT BEAM     0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0  14.0  40.1  61.0  72.6  68.6  25.8   0.0
SOLAR LOAD      0.0   0.0   0.0   0.0   0.0   0.0   0.0   5.0   9.2  13.8  17.4  19.8  21.6  36.8  63.3  83.4  92.4  83.7  42.3   0.0
S.H.G.F.        0.0   0.0   0.0   0.0   0.0   0.0   0.0   3.6   6.6  10.0  12.5  14.3  15.5  19.4  41.3  62.5  71.8  66.1  33.5   0.0
SOL. AIR    O  51.8  51.7  50.4  49.9  50.3  49.0  48.7  49.8  51.8  52.7  50.6  47.3  47.6  48.8  51.9  51.5  52.9  49.9  41.7  33.3
DRY BULB    O  51.8  51.7  50.4  49.9  50.3  49.0  48.7  49.1  50.4  50.6  48.0  44.3  44.4  43.3  42.4  39.0  39.0  37.3  35.4  33.3
WET BULB    O  48.8  48.8  47.7  47.2  47.6  46.0  45.3  45.2  46.6  46.6  43.9  39.9  40.8  40.1  39.4  35.5  35.6  33.9  31.6  29.3
LONG. RAD.  O 108.4 108.2 107.3 106.8 107.0 106.1 105.8 106.3 107.7 108.2 106.5 103.7 103.7 103.8 104.7 103.5 103.9 102.2  98.2  93.9
SHORT RAD.  O 108.2 108.1 107.0 106.6 106.9 105.8 105.6 107.9 110.7 112.7 112.0 109.9 110.7 115.9 125.8 131.1 134.7 129.9 111.9  93.4
CONV.       O  -1.0  -0.7  -1.0  -0.8  -0.5  -1.0  -0.7  -2.0  -3.0  -4.9  -7.1  -8.5  -7.8 -12.7 -21.0 -28.6 -30.8 -29.0 -16.6  -3.0
HEAT FLUX   O  -1.3  -0.8  -1.3  -1.0  -0.5  -1.3  -0.9  -0.4   0.0  -0.3  -1.6  -2.3  -0.8  -0.6   0.1  -1.1   0.0  -1.2  -2.8  -3.6
SUR. TEMP.  O  52.1  51.9  50.7  50.1  50.4  49.3  48.9  49.6  51.2  51.8  49.8  46.4  46.4  46.5  47.7  46.2  46.7  44.5  39.5  34.1
SUR. TEMP.  I  59.0  58.4  57.4  56.8  56.8  56.1  55.6  56.2  57.3  57.9  56.7  54.2  53.2  52.3  51.5  49.4  48.5  47.2  45.3  45.6
HEAT FLUX   I  -0.2  -0.5  -0.4  -0.5  -0.7  -0.5  -0.6  -0.9  -1.1  -0.9  -0.3   0.1  -0.4  -0.3  -0.2   0.4   0.1   0.2   0.1  -1.1
CONV.       I  -0.2  -0.5  -0.4  -0.5  -0.7  -0.5  -0.6  -0.9  -1.1  -0.9  -0.3   0.1  -0.4  -0.3  -0.2   0.4   0.1   0.2   0.1  -1.1
DRY BULB    I  59.1  58.7  57.7  57.2  57.3  56.4  56.0  56.8  58.0  58.5  56.9  54.1  53.5  52.5  51.7  49.1  48.5  47.0  45.2  46.4
```

J2. Continued

```
DATA FOR 12 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   3.250   DECLINATION =   4.144

WEST WALL    SURFACE TILT =  90.00  SURFACE AZIMUTH =  90.00

CLOCK TIME   21.00 22.00 23.00 24.00

SOLAR TIME    0.0   0.0   0.0   0.0

ALTITUDE       0.0   0.0   0.0   0.0

AZIMUTH        0.0   0.0   0.0   0.0

D. INTENSITY   0.0   0.0   0.0   0.0

DIRECT BEAM    0.0   0.0   0.0   0.0

SOLAR LOAD     0.0   0.0   0.0   0.0

S.H.G.F.       0.0   0.0   0.0   0.0

SOL. AIR    O 33.7  33.8  33.8  33.7

DRY BULB    O 33.7  33.8  33.8  33.7

WET BULB    O 30.1  29.9  30.1  30.1

LONG. RAD. O 93.9  94.0  94.0  93.9

SHORT RAD. O 93.7  93.8  93.8  93.7

CONV.       O -1.1  -1.1  -1.1  -1.2

HEAT FLUX   O -1.3  -1.3  -1.3  -1.4

SUR. TEMP. O 34.0  34.1  34.1  34.0

SUR. TEMP. I 45.8  46.5  46.5  46.6

HEAT FLUX   I -1.3  -1.5  -1.3  -1.4

CONV.       I -1.3  -1.5  -2.0  -1.4

DRY BULB    I 46.7  47.8  47.8  47.6
```

J2. Continued

```
DATA FOR 12 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   3.250   DECLINATION =   4.144

EAST WALL    SURFACE TILT =  90.00  SURFACE AZIMUTH = -90.00

CLOCK TIME     1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00 12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00

SOLAR TIME     0.0   0.0   0.0   0.0   0.0   0.0   0.0  -5.50 -4.50 -3.50 -2.50 -1.50 -0.50  0.50  1.50  2.50  3.50  4.50  5.50  0.0

ALTITUDE        0.0   0.0   0.0   0.0   0.0   0.0   0.0   7.8  16.6  24.9  32.0  37.5  40.4  40.4  37.5  32.0  24.9  16.6   7.8   0.0

AZIMUTH         0.0   0.0   0.0   0.0   0.0   0.0   0.0 -86.5 -74.1 -60.7 -45.7 -28.7  -9.8   9.8  28.7  45.7  60.7  74.1  86.5   0.0

D. INTENSITY    0.0   0.0   0.0   0.0   0.0   0.0   0.0  52.8  74.5  91.7 100.5 105.1 107.2 107.2 105.1 100.5  91.7  74.5  36.2   0.0

DIRECT BEAM     0.0   0.0   0.0   0.0   0.0   0.0   0.0  52.2  68.6  72.6  61.0  40.1  13.9   0.0   0.0   0.0   0.0   0.0   0.0   0.0

SOLAR LOAD      0.0   0.0   0.0   0.0   0.0   0.0   0.0  61.7  83.7  92.4  83.4  63.3  36.8  21.6  19.8  17.4  13.8   9.2   3.4   0.0

S.H.G.F.        0.0   0.0   0.0   0.0   0.0   0.0   0.0  48.8  66.1  71.8  62.5  41.3  19.4  15.5  14.3  12.5  10.0   6.6   2.4   0.0

SOL. AIR    O  51.8  51.7  50.4  49.9  50.3  49.0  48.7  58.4  63.0  64.5  60.5  53.8  49.9  46.5  45.4  41.6  41.1  38.7  35.9  33.3

DRY BULB    O  51.8  51.7  50.4  49.9  50.3  49.0  48.7  49.1  50.4  50.6  48.0  44.3  44.4  43.3  42.4  39.0  39.0  37.3  35.4  33.3

WET BULB    O  48.8  48.6  47.7  47.2  47.6  46.0  45.3  45.2  46.6  46.6  43.9  39.9  40.8  40.1  39.4  35.5  35.6  33.9  31.6  29.3

LONG. RAD.  O 108.4 108.2 107.3 106.8 107.0 106.1 105.6 109.9 112.7 113.6 111.1 106.7 104.8 102.9 102.0  99.3  98.9  97.3  95.8  93.7

SHORT RAD.  O 108.2 108.1 107.0 106.6 106.9 105.8 105.6 130.6 140.5 144.2 138.4 127.3 116.8 109.8 108.4 104.7 103.3 100.1  96.2  93.4

CONV.       O  -1.0  -0.7  -1.0  -0.8  -0.5  -1.0  -0.7 -18.8 -26.5 -30.1 -28.8 -23.3 -13.6  -8.7  -7.6  -7.8  -5.5  -4.6  -2.8  -1.9

HEAT FLUX   O  -1.3  -0.8  -1.3  -1.0  -0.5  -1.3  -0.9   1.9   1.3   0.5  -1.5  -2.7  -1.6  -1.8  -1.3  -2.4  -1.1  -1.8  -2.0  -2.2

SUR. TEMP.  O  52.1  51.9  50.7  50.1  50.4  49.3  48.9  53.8  57.0  58.1  55.2  50.1  47.8  45.5  44.3  41.0  40.4  38.4  36.1  33.8

SUR. TEMP.  I  59.0  58.4  57.4  56.8  56.8  56.1  55.6  56.3  57.6  58.3  57.1  54.5  53.4  52.3  51.4  49.1  48.2  46.7  45.0  45.5

HEAT FLUX   I  -0.2  -0.5  -0.4  -0.5  -0.7  -0.5  -0.6  -0.7  -0.6  -0.3   0.3   0.5  -0.2  -0.3  -0.4  -0.0  -0.5  -0.4  -0.3  -1.3

CONV.       I  -0.2  -0.5  -0.4  -0.5  -0.7  -0.5  -0.6  -0.7  -0.6  -0.3   0.3   0.5  -0.2  -0.3  -0.4  -0.0  -0.5  -0.4  -0.3  -1.3

DRY BULB    I  59.1  58.7  57.7  57.2  57.3  56.4  56.0  56.8  58.0  58.5  56.9  54.1  53.5  52.5  51.7  49.1  48.6  47.0  45.2  46.4
```

J2. Continued

```
DATA FOR 12 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   3.250   DECLINATION =   4.144

EAST WALL     SURFACE TILT =  90.00  SURFACE AZIMUTH = -90.00

CLOCK TIME    21.00 22.00 23.00 24.00

SOLAR TIME     0.0   0.0   0.0   0.0

ALTITUDE        0.0   0.0   0.0   0.0

AZIMUTH         0.0   0.0   0.0   0.0

D. INTENSITY    0.0   0.0   0.0   0.0

DIRECT BEAM     0.0   0.0   0.0   0.0

SOLAR LOAD      0.0   0.0   0.0   0.0

S.H.G.F.        0.0   0.0   0.0   0.0

SOL. AIR    O  33.7  33.8  33.8  33.7

DRY BULB    O  33.7  33.8  33.8  33.7

WET BULB    O  30.1  29.9  30.1  30.1

LONG. RAD. O  93.9  94.0  94.0  93.9

SHORT RAD. O  93.7  93.8  93.8  93.7

CONV.       O  -1.0  -1.0  -1.1  -1.2

HEAT FLUX   O  -1.2  -1.2  -1.3  -1.4

SUR. TEMP. O  33.9  34.1  34.1  34.0

SUR. TEMP. I  45.8  46.4  46.4  46.6

HEAT FLUX   I  -1.4  -1.5  -1.3  -1.4

CONV.       I  -1.4  -1.5  -2.0  -1.4

DRY BULB    I  46.7  47.8  47.8  47.6
```

J2. Continued

DATA FOR 12 SEPT 73 LATITUDE = 53.34 LONGITUDE = 113.31 TIME ZONE = 7. DST= 1. LOCATION EDMONTON

EQUATION OF TIME = 3.250 DECLINATION = 4.144

NORTH WALL SURFACE TILT = 90.00 SURFACE AZIMUTH = 180.00

CLOCK TIME		1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00
SOLAR TIME		0.0	0.0	0.0	0.0	0.0	0.0	0.0	-5.50	-4.50	-3.50	-2.50	-1.50	-0.50	0.50	1.50	2.50	3.50	4.50	5.50	0.0
ALTITUDE		0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.8	16.6	24.9	32.0	37.5	40.4	40.4	37.5	32.0	24.9	16.6	7.8	0.0
AZIMUTH		0.0	0.0	0.0	0.0	0.0	0.0	0.0	-88.5	-74.1	-60.7	-45.7	-28.7	-9.8	9.8	28.7	45.7	60.7	74.1	88.5	0.0
B. INTENSITY		0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.8	74.5	91.7	100.5	105.1	107.2	107.2	105.1	100.5	91.7	74.5	36.2	0.0
DIRECT BEAM		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SOLAR LOAD		0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4	9.2	13.8	17.4	19.8	21.0	21.0	19.8	17.4	13.8	9.2	3.7	0.0
S.H.G.F.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9	6.6	10.0	12.5	14.3	15.2	15.2	14.3	12.5	10.0	6.6	2.6	0.0
SOL. AIR	O	51.8	51.7	50.4	49.9	50.3	49.0	48.7	49.9	51.8	52.7	50,6	47.3	47.6	46.5	45.4	41.6	41.1	38.7	36.0	33.3
DRY BULB	O	51.8	51.7	50.4	49.9	50.3	49.0	48.7	49.1	50.4	50.6	48.0	44.3	44.4	43.3	42.4	39.0	39.0	37.3	35.4	33.3
WET BULB	O	48.8	48.8	47.7	47.2	47.6	46.0	45.3	45.2	46.6	46.6	43.9	39.9	40.8	40.1	39.4	35.5	35.6	33.9	31.6	29.3
LONG. RAD.	O	108.4	108.2	107.3	106.8	107.0	106.1	105.8	106.3	107.7	108.2	106.5	103.7	103.6	102.8	102.0	99.3	98.9	97.3	95.5	93.7
SHORT RAD.	O	108.2	108.1	107.0	106.6	106.9	105.8	105.6	108.1	110.7	112.7	112.0	109.9	110.5	109.6	108.4	104.7	103.3	100.1	96.4	93.4
CONV.	O	-1.0	-0.7	-1.0	-0.8	-0.5	-1.0	-0.7	-2.1	-3.0	-4.9	-7.1	-8.5	-7.7	-8.0	-7.6	-7.8	-5.5	-4.6	-2.9	-1.9
HEAT FLUX	O	-1.3	-0.8	-1.3	-1.0	-0.5	-1.3	-0.9	-0.4	0.0	-0.3	-1.6	-2.3	-0.8	-1.2	-1.2	-2.4	-1.1	-1.8	-2.0	-2.2
SUR. TEMP.	O	52.1	51.9	50.7	50.1	50.4	49.3	48.9	49.6	51.2	51.8	49.8	46.4	46.3	45.3	44.3	40.9	40.4	38.4	36.1	33.8
SUR. TEMP.	I	59.0	58.4	57.4	56.8	56.8	56.1	55.6	56.2	57.3	57.9	56.7	54.2	53.2	52.2	51.4	49.1	48.2	46.7	45.0	48.8
HEAT FLUX	I	-0.2	-0.5	-0.4	-0.5	-0.7	-0.5	-0.6	-0.9	-1.1	-0.9	-0.3	0.1	-0.4	-0.4	-0.5	-0.0	-0.5	-0.4	-0.3	-1.3
CONV.	I	-0.2	-0.5	-0.4	-0.5	-0.7	-0.5	-0.6	-0.9	-1.1	-0.9	-0.3	0.1	-0.4	-0.4	-0.5	-0.0	-0.5	-0.4	-0.3	-1.3
DRY BULB	I	59.1	58.7	57.7	57.2	57.3	56.4	56.0	56.8	58.0	58.5	56.9	54.1	53.5	52.8	51.7	49.1	48.8	47.0	46.2	46.4

J2. Continued

```
DATA FOR 12 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON
EQUATION OF TIME =   3.250   DECLINATION =   4.144
NORTH WALL   SURFACE TILT =  90.00  SURFACE AZIMUTH = 180.00
CLOCK TIME    21.00 22.00 23.00 24.00
SOLAR TIME     0.0   0.0   0.0   0.0
ALTITUDE        0.0   0.0   0.0   0.0
AZIMUTH         0.0   0.0   0.0   0.0
D. INTENSITY    0.0   0.0   0.0   0.0
DIRECT BEAM     0.0   0.0   0.0   0.0
SOLAR LOAD      0.0   0.0   0.0   0.0
S.H.G.F.        0.0   0.0   0.0   0.0
SOL. AIR    O  33.7  33.8  33.8  33.7
DRY BULB    O  33.7  33.8  33.8  33.7
WET BULB    O  30.1  29.9  30.1  30.1
LONG. RAD. O   93.9  94.0  94.0  93.9
SHORT RAD. O   93.7  93.8  93.8  93.7
CONV.       O  -1.0  -1.0  -1.1  -1.2
HEAT FLUX   O  -1.2  -1.2  -1.3  -1.4
SUR. TEMP. O   33.9  34.1  34.1  34.0
SUR. TEMP. I   45.8  46.4  46.4  46.6
HEAT FLUX   I  -1.4  -1.5  -1.3  -1.4
CONV.       I  -1.4  -1.8  -2.0  -1.4
DRY BULB    I  46.7  47.5  47.8  47.6
```

J2. Continued

```
DATA FOR 12 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   3.260   DECLINATION =   4.144

WEST SLOPE   SURFACE TILT =  20.50  SURFACE AZIMUTH =  90.00

CLOCK TIME     1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00 12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00

SOLAR TIME    0.0   0.0   0.0   0.0   0.0   0.0   0.0  -5.50 -4.50 -3.50 -2.50 -1.50 -0.50  0.50  1.50  2.50  3.50  4.50  5.50  0.0

ALTITUDE        0.0   0.0   0.0   0.0   0.0   0.0   0.0   7.8  16.6  24.9  32.0  37.5  40.4  40.4  37.5  32.0  24.9  16.6   7.8   0.0

AZIMUTH         0.0   0.0   0.0   0.0   0.0   0.0   0.0 -86.5 -74.1 -60.7 -45.7 -28.7  -9.8   9.8  28.7  45.7  60.7  74.1  86.5   0.0

D. INTENSITY    0.0   0.0   0.0   0.0   0.0   0.0   0.0  52.8  74.5  91.7 100.5 105.1 107.2 107.2 105.1 100.5  91.7  74.5  36.2   0.0

DIRECT BEAM     0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0  10.7  28.6  45.8  60.2  70.0  73.9  71.3  61.5  44.0  17.1   0.0

SOLAR LOAD      0.0   0.0   0.0   0.0   0.0   0.0   0.0   5.3   7.6  20.1  39.0  56.8  71.4  81.1  84.9  81.7  71.0  51.8  20.8   0.0

S.H.G.F.        0.0   0.0   0.0   0.0   0.0   0.0   0.0   3.8   5.5   8.8  21.3  38.5  52.9  62.0  65.6  63.2  54.5  38.7  14.6   0.0

SOL. AIR    O  51.8  51.7  50.4  49.9  50.3  49.0  48.7  49.0  51.5  53.6  53.8  52.8  55.1  55.5  55.1  51.3  49.6  45.0  38.5  33.3

DRY BULB    O  51.8  51.7  50.4  49.9  50.3  49.0  48.7  49.1  50.4  50.6  48.0  44.3  44.4  43.3  42.4  39.0  39.0  37.3  35.4  33.3

WET BULB    O  48.8  48.8  47.7  47.2  47.6  46.0  45.3  45.2  46.6  46.6  43.9  39.9  40.8  40.1  39.4  35.5  35.6  33.9  31.6  29.3

LONG. RAD. O 109.7 109.4 108.5 108.0 108.2 107.3 106.9 107.8 109.2 111.1 111.7 111.3 113.1 113.7 113.6 110.6 108.9 105.1  99.6  95.2

SHORT RAD. O 109.4 109.3 108.2 107.8 108.1 107.0 106.7 111.4 114.4 124.9 138.1 149.6 161.7 168.8 171.1 165.8 157.0 139.8 113.1  94.4

CONV.       O  -1.3  -0.7  -1.2  -0.9  -0.4  -1.2  -0.8  -3.6  -4.7 -12.8 -26.2 -38.8 -47.0 -54.2 -57.2 -57.1 -49.2 -37.7 -18.4  -4.1

HEAT FLUX   O  -1.6  -0.8  -1.5  -1.1  -0.5  -1.5  -1.0   0.1   0.5   1.0   0.2  -0.6   1.6   0.8   0.3  -1.9  -1.1  -3.1  -5.0  -4.8

SUR. TEMP. O  52.1  51.9  50.7  50.1  50.4  49.3  48.9  50.0  51.6  53.8  54.5  54.0  56.1  56.9  56.7  53.3  51.3  46.7  40.0  34.3

SUR. TEMP. I  59.0  58.4  57.5  56.9  56.9  56.1  55.7  56.3  57.4  58.0  57.0  54.6  53.8  52.9  52.1  49.9  48.9  47.4  45.4  45.7

HEAT FLUX   I  -0.1  -0.5  -0.4  -0.5  -0.7  -0.4  -0.5  -0.9  -1.0  -0.7   0.1   0.8   0.4   0.7   0.7   1.2   0.6   0.6   0.3  -1.1

CONV.       I  -0.1  -0.5  -0.3  -0.5  -0.7  -0.4  -0.5  -0.9  -1.0  -0.7   0.1   0.8   0.4   0.7   0.7   1.2   0.6   0.6   0.3  -1.1

DRY BULB    I  59.1  58.7  57.7  57.2  57.3  56.4  56.0  56.6  58.0  58.6  56.9  54.1  53.6  52.6  51.7  49.1  48.6  47.8  45.8  46.4
```

J2. Continued

```
DATA FOR 12 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   3.250   DECLINATION =   4.144

WEST SLOPE   SURFACE TILT =  20.50  SURFACE AZIMUTH =  90.00

CLOCK TIME   21.00 22.00 23.00 24.00

SOLAR TIME    0.0   0.0   0.0   0.0

ALTITUDE       0,0   0.0   0.0   0.0

AZIMUTH        0.0   0.0   0.0   0.0

D. INTENSITY   0.0   0.0   0.0   0.0

DIRECT BEAM    0.0   0.0   0.0   0.0

SOLAR LOAD     0.0   0.0   0.0   0.0

S.H.G.F.       0.0   0.0   0.0   0.0

SOL. AIR    O 33.7  33.8  33.8  33.7

DRY BULB    O 33.7  33.8  33.8  33.7

WET BULB    O 30.1  29.9  30.1  30.1

LONG. RAD. O 94.9  95.0  95.0  94.9

SHORT RAD. O 94.7  94.8  94.8  94.7

CONV.       O -1.2  -1.0  -1.1  -1.2

HEAT FLUX  O -1.4  -1.2  -1.3  -1.4

SUR. TEMP. O 34.0  34.1  34.1  34.0

SUR. TEMP. I 45.9  46.6  46.6  46.8

HEAT FLUX  I -1.3  -1.5  -1.3  -1.4

CONV.       I -1.3  -1.8  -0.9  -1.4

DRY BULB    I 46.9  47.5  [illegible]  47.6
```

J2. Continued

```
DATA FOR 12 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON
EQUATION OF TIME =   3.250   DECLINATION =   4.144
EAST SLOPE   SURFACE TILT =  20.50  SURFACE AZIMUTH = -90.00
CLOCK TIME     1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00 12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00
SOLAR TIME     0.0   0.0   0.0   0.0   0.0   0.0   0.0  -5.50 -4.50 -3.50 -2.50 -1.50 -0.50  0.50  1.50  2.50  3.50  4.50  5.50  0.0
ALTITUDE        0.0   0.0   0.0   0.0   0.0   0.0   0.0   7.8  16.6  24.9  32.0  37.8  40.4  40.4  37.8  32.0  24.9  16.6   7.8   0.0
AZIMUTH         0.0   0.0   0.0   0.0   0.0   0.0   0.0 -86.5 -74.1 -60.7 -45.7 -28.7  -9.8   9.8  28.7  45.7  60.7  74.1  86.5   0.0
B. INTENSITY    0.0   0.0   0.0   0.0   0.0   0.0   0.0  52.8  74.5  91.7 100.5 105.1 107.2 107.2 105.1 100.5  91.7  74.5  36.2   0.0
DIRECT BEAM     0.0   0.0   0.0   0.0   0.0   0.0   0.0  25.0  44.0  61.5  71.3  73.9  70.0  60.2  45.8  28.6  10.7   0.0   0.0   0.0
SOLAR LOAD      0.0   0.0   0.0   0.0   0.0   0.0   0.0  30.3  51.6  71.0  81.7  84.9  81.1  71.4  56.8  39.0  20.1   7.6   3.7   0.0
S.H.G.F.        0.0   0.0   0.0   0.0   0.0   0.0   0.0  21.3  38.7  54.5  63.2  65.6  62.0  52.9  38.5  21.3   8.8   5.8   2.6   0.0
SOL. AIR    O  51.8  51.7  50.4  49.9  50.3  49.0  48.7  52.7  58.1  61.2  60.3  57.0  56.6  54.0  50.9  44.8  42.0  38.4  35.9  33.3
DRY BULB    O  51.8  51.7  50.4  49.9  50.3  49.0  48.7  49.1  50.4  50.6  48.0  44.3  44.4  43.3  42.4  39.0  39.0  37.3  35.4  33.3
WET BULB    O  48.8  48.8  47.7  47.2  47.6  46.0  45.3  45.2  46.6  46.6  43.5  39.9  40.8  40.1  39.4  35.5  35.6  33.9  31.6  29.3
LONG. RAD.  O 109.7 109.4 108.5 108.0 108.2 107.3 106.9 111.C 115.2 118.4 118.1 115.6 114.9 112.7 109.9 104.9 102.1  99.0  96.9  94.9
SHORT RAD.  O 109.4 109.3 108.2 107.8 108.1 107.0 106.7 131.9 150.4 166.5 173.2 172.7 169.7 160.8 148.1 130.8 115.3 103.7  99.0  94.4
CONV.       O  -1.3  -0.7  -1.2  -0.9  -0.4  -1.2  -0.8 -18.2 -32.1 -45.5 -54.9 -58.6 -54.9 -49.5 -40.2 -30.1 -16.1  -7.9  -4.8  -2.5
HEAT FLUX   O  -1.6  -0.8  -1.5  -1.1  -0.5  -1.5  -1.0   2.8   3.2   2.7   0.2  -1.5  -0.1  -1.4  -2.1  -4.2  -2.9  -3.3  -2.7  -2.9
SUR. TEMP.  O  52.1  51.9  50.7  50.1  50.4  49.3  48.9  53.6  58.4  62.0  61.7  58.9  58.1  55.7  52.5  46.5  43.0  39.3  36.6  33.9
SUR. TEMP.  I  59.0  58.4  57.8  56.9  56.9  56.1  55.7  56.4  57.7  58.6  57.4  54.9  54.0  52.9  52.0  49.5  48.5  46.9  45.1  45.6
HEAT FLUX   I  -0.1  -0.5  -0.4  -0.5  -0.7  -0.4  -0.8  -0.7  -0.5  -0.0   0.8   1.3   0.8   0.7   0.8   0.7  -0.1  -0.1  -0.2  -1.3
CONV.       I  -0.1  -0.6  -0.3  -0.5  -0.7  -0.4  -0.5  -0.7  -0.8  -0.0   0.8   1.3   0.8   0.7   0.8   0.7  -0.1  -0.1  -0.2  -1.3
DRY BULB    I  59.1  58.7  57.7  57.2  57.3  56.4  56.0  56.8  58.0  56.8  54.9  54.1  53.5  52.8  51.7  49.1  48.8  47.8  46.2  46.4
```

J2. Continued

```
DATA FOR 12 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON
EQUATION OF TIME =   3.250   DECLINATION =   4.144
EAST SLOPE   SURFACE TILT =  20.50  SURFACE AZIMUTH = -90.00
CLOCK TIME   21.00 22.00 23.00 24.00
SOLAR TIME    0.0   0.0   0.0   0.0
ALTITUDE       0.0   0.0   0.0   0.0
AZIMUTH        0.0   0.0   0.0   0.0
D. INTENSITY   0.0   0.0   0.0   0.0
DIRECT BEAM    0.0   0.0   0.0   0.0
SOLAR LOAD     0.0   0.0   0.0   0.0
S.H.G.F.       0.0   0.0   0.0   0.0
SOL. AIR    O 33.7  33.8  33.8  33.7
DRY BULB    O 33.7  33.8  33.8  33.7
WET BULB    O 30.1  29.9  30.1  30.1
LONG. RAD. O 94.9  95.0  95.0  94.9
SHORT RAD. O 94.7  94.8  94.8  94.7
CONV.       O -1.0  -1.0  -1.1  -1.2
HEAT FLUX  O -1.2  -1.2  -1.3  -1.4
SUR. TEMP. O 34.0  34.0  34.1  34.0
SUR. TEMP. I 46.6  46.5  46.5  46.7
HEAT FLUX  I -1.2  -1.6  -1.3  -1.4
CONV.       I -1.8  -1.6  -2.1  -1.4
DRY BULB    I 46.7  47.5  47.8  47.6
```

J2. Continued

```
DATA FOR 12 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON
EQUATION OF TIME =   3.250   DECLINATION =   4.144
HORIZONTAL   SURFACE TILT =   0.0   SURFACE AZIMUTH =   0.0
CLOCK TIME      1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.03  9.00 10.00 11.00 12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00
SOLAR TIME      0.0   0.0   0.0   0.0   0.0   0.0   0.0  -5.50 -4.50 -3.50 -2.50 -1.50 -0.50  0.50  1.50  2.50  3.50  4.50  5.50  0.0
ALTITUDE         0.0   0.0   0.0   0.0   0.0   0.0   0.0   7.8  16.6  24.9  32.0  37.5  40.4  40.4  37.5  32.0  24.9  16.6   7.8   0.0
AZIMUTH          0.0   0.0   0.0   0.0   0.0   0.0   0.0 -86.5 -74.1 -60.7 -45.7 -28.7  -9.8   9.8  28.7  45.7  60.7  74.1  86.5   0.0
D. INTENSITY     0.0   0.0   0.0   0.0   0.0   0.0   0.0  52.8  74.5  91.7 100.5 105.1 107.2 107.2 105.1 100.5  91.7  74.5  36.2   0.0
DIRECT BEAM      0.0   0.0   0.0   0.0   0.0   0.0   0.0   7.2  21.3  38.6  53.3  63.9  69.5  69.5  63.9  53.3  38.6  21.3   4.9   0.0
SOLAR LOAD       0.0   0.0   0.0   0.0   0.0   0.0   0.0  12.6  28.9  48.0  63.6  74.7  80.5  80.5  74.7  63.6  48.0  28.9   8.6   0.0
S.H.G.F.         0.0   0.0   0.0   0.0   0.0   0.0   0.0   5.5  15.9  32.0  46.4  56.4  61.5  61.5  56.4  46.4  32.0  15.8   3.8   0.0
SOL. AIR    O  51.8  51.7  50.4  49.9  50.3  49.0  48.7  50.0  54.7  57.8  57.5  55.5  56.5  55.4  53.6  48.5  46.2  41.6  36.7  33.3
DRY BULB    O  51.8  51.7  50.4  49.9  50.3  49.0  48.7  49.1  50.4  50.6  48.0  44.3  44.4  43.3  42.4  39.0  39.0  37.3  35.4  33.3
WET BULB    O  48.8  48.8  47.7  47.2  47.6  46.0  45.3  45.2  46.6  46.6  43.9  39.9  40.8  40.1  39.4  35.8  35.6  33.9  31.6  29.3
LONG. RAD.  O 109.8 109.5 108.5 108.0 108.1 107.2 106.9 108.7 111.9 114.9 115.3 114.0 114.6 113.9 112.4 108.3 105.9 102.1  97.9  95.0
SHORT RAD.  O 109.4 109.3 108.2 107.8 108.1 107.0 106.7 117.4 131.9 147.7 158.3 164.4 169.2 168.3 162.8 151.0 138.2 121.2 103.1  94.4
CONV.       O  -1.7  -0.9  -1.3  -0.9  -0.3  -1.0  -0.5  -7.5 -17.3 -30.1 -42.3 -51.2 -53.8 -54.8 -51.6 -46.3 -34.8 -23.1  -9.8  -3.2
HEAT FLUX   O  -2.0  -1.1  -1.6  -1.1  -0.3  -1.2  -0.7   1.3   2.7   2.7   0.8  -0.7   0.7  -0.5  -1.2  -3.6  -2.5  -4.0  -4.6  -3.7
SUR. TEMP.  O  52.2  51.9  50.7  50.1  50.4  49.2  48.8  51.0  54.7  58.1  58.6  57.1  57.9  57.0  55.3  50.6  47.7  43.1  37.9  34.1
SUR. TEMP.  I  62.5  60.0  57.8  56.0  54.6  53.4  52.3  51.8  52.2  53.4  54.6  55.3  55.9  56.2  56.1  55.2  53.6  51.4  48.2  45.3
HEAT FLUX   I  -0.0   0.0  -0.0  -0.0   0.0  -0.0  -0.0  -0.0  -0.0  -0.0   0.0   0.0   0.0  -0.0   0.0   0.0   0.0   0.0   0.0   0.0
CONV.       I   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0
DRY BULB    I  59.1  58.7  57.7  57.2  57.3  56.4  56.0  54.8  58.0  58.5  56.9  54.1  53.5  52.5  51.7  49.1  48.5  47.8  45.2  46.4
```

J2. Continued

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DATA FOR 12 SEPT 73  LATITUDE =  53.34 LONGITUDE = 113.31   TIME ZONE = 7.  DST= 1.    LOCATION   EDMONTON

EQUATION OF TIME =   3.250   DECLINATION =   4.144

HORIZONTAL   SURFACE TILT =   0.0   SURFACE AZIMUTH =   0.0

CLOCK TIME   21.00 22.00 23.00 24.00

SOLAR TIME    0.0   0.0   0.0   0.0

ALTITUDE       0.0   0.0   0.0   0.0

AZIMUTH        0.0   0.0   0.0   0.0

D. INTENSITY   0.0   0.0   0.0   0.0

DIRECT BEAM    0.0   0.0   0.0   0.0

SOLAR LOAD     0.0   0.0   0.0   0.0

S.H.G.F.       0.0   0.0   0.0   0.0

SOL. AIR   O  33.7  33.8  33.8  33.7

DRY BULB   O  33.7  33.8  33.8  33.7

WET BULB   O  30.1  29.9  30.1  30.1

LONG. RAD. O  94.9  94.9  94.9  94.8

SHORT RAD. O  94.7  94.8  94.8  94.7

CONV.      O  -0.9  -0.6  -0.6  -0.5

HEAT FLUX  O  -1.1  -0.8  -0.7  -0.7

SUR. TEMP. O  33.9  34.0  33.9  33.8

SUR. TEMP. I  42.5  40.5  40.5  38.8

HEAT FLUX  I  -0.0  -0.0  -0.7  -0.0

CONV.      I   0.0   0.0   0.0   0.0

DRY BULB   I  46.7  47.5  47.8  47.6
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J3. Heat Transfer

HOURLY HEAT FLOWS THROUGH THE STRUCTURAL COMPONENTS

WALLS	DOORS	FLOOR	HOR.ROOF	PIT.ROOF	WINDOWS	TOTAL	HR
-646.31	-808.42	-642.75	0.0	-1384.17	-186.71	-3538.38	1
-584.87	-907.11	-550.61	0.0	-1138.17	-189.42	-3350.19	2
-531.89	-910.48	-566.35	0.0	-1054.20	-194.83	-3257.74	3
-99.83	-837.06	-629.28	0.0	-60.61	-216.46	-1843.26	4
-593.84	-872.27	-589.94	0.0	-1186.13	-202.95	-3444.83	5
-552.54	-855.40	-605.68	0.0	-1088.82	-208.36	-3310.49	6
-994.25	-906.11	-558.46	0.0	-2094.67	-192.12	-4745.62	7
-1380.64	-977.92	-542.75	0.0	-2900.21	1494.49	-4307.04	8
-1391.76	-1007.70	-582.08	0.0	-2596.99	4256.87	-1321.64	9
-1832.48	-1057.69	-487.69	0.0	-3092.11	3740.91	-2769.06	10
-1418.38	-1070.31	-495.55	0.0	-1218.98	4248.97	48.78	11
-1313.57	-1076.26	-448.36	0.0	47.92	2782.96	-7.31	12
-772.98	-1027.44	-440.49	0.0	2085.69	1236.09	1080.87	13
-980.79	-1051.49	-424.76	0.0	3285.89	962.13	1790.98	14
-231.98	-1053.72	-416.90	0.0	2578.73	878.05	1751.18	15
40.65	-1061.29	-424.76	0.0	3154.42	750.67	2459.69	16
-120.56	-1141.06	-377.57	0.0	1979.17	589.55	929.54	17
176.06	-1165.98	-377.57	0.0	1758.91	358.87	750.29	18
243.32	-1185.97	-369.70	0.0	1259.42	70.57	17.64	19
1428.67	-991.04	-527.02	0.0	3585.27	-181.30	3311.78	20
1009.27	-945.61	-550.62	0.0	2463.41	-189.42	1787.03	21
453.12	-1101.68	-566.35	0.0	1163.50	-194.83	-246.24	22
418.79	-1101.83	-597.81	0.0	1087.53	-205.65	-398.97	23
-35.74	-1101.82	-582.08	0.0	58.61	-200.24	-1861.27	24
-677.43	-1101.82	-527.02	0.0	-1399.02	-181.30	-3886.58	25
-1029.38	-1101.82	-487.69	0.0	-2195.81	-167.77	-4982.48	26
-714.76	-1101.82	-519.15	0.0	-1473.96	-178.59	-3988.29	27
-469.82	-1101.82	-550.62	0.0	-913.74	-189.42	-3225.42	28
-793.17	-1101.82	-534.88	0.0	-1397.66	-184.01	-4011.54	29
-624.06	-1101.82	-542.75	0.0	-1412.44	-186.71	-3867.78	30
-327.01	-1101.82	-582.08	0.0	-611.27	-200.24	-2822.42	31
-1271.43	-738.31	-550.62	0.0	-2640.48	2021.43	-3179.38	32
-1569.82	-1034.52	-534.88	0.0	-2986.43	4414.49	-1711.16	33
-1393.90	-1079.21	-511.29	0.0	-1961.40	4725.92	-219.88	34
-1063.48	-1056.21	-511.29	0.0	-327.40	4191.73	1233.37	35
-1164.14	-1078.53	-448.36	0.0	371.27	2787.77	438.00	36
-893.30	-1062.81	-416.90	0.0	1765.56	1226.92	619.46	37
-964.45	-1108.29	-369.70	0.0	1880.60	938.32	376.47	38
-871.16	-1183.59	-314.64	0.0	1443.48	667.19	-258.71	39
-188.00	-1165.05	-338.23	0.0	2351.05	756.65	1416.40	40
-55.67	-1215.29	-306.77	0.0	1826.39	439.20	687.85	41
741.14	-1154.29	-385.43	0.0	2776.86	234.13	2212.40	42
913.75	-1113.60	-432.63	0.0	2628.48	-26.41	1969.59	43
530.11	-1107.17	-432.63	0.0	1463.96	-148.83	305.48	44
1482.83	-911.64	-597.81	0.0	3526.92	-205.65	3294.64	45
30.98	-1012.95	-495.55	0.0	189.39	-170.48	-1458.60	46
-51.15	-1080.74	-519.15	0.0	8.91	-178.59	-1820.72	47
497.56	-1080.79	-613.84	0.0	1271.93	-211.07	-135.90	48
-181.46	-1080.78	-574.21	0.0	-269.55	-197.54	-2303.54	49
-557.96	-1080.78	-550.62	0.0	-1121.88	-189.42	-3500.63	50
-443.42	-1080.78	-574.21	0.0	-853.15	-197.54	-3149.11	51
-589.39	-1080.78	-574.21	0.0	-1181.82	-197.54	-3623.75	52
-789.73	-1080.78	-550.62	0.0	-1630.89	-189.42	-4249.14	53
-622.08	-1080.78	-582.08	0.0	-1084.86	-200.24	-3410.02	54
-638.14	-1080.78	-574.21	0.0	-1290.14	-197.54	-3780.81	55
-944.81	-670.97	-605.68	0.0	-1903.87	1093.63	-2831.69	56
-1013.38	-911.91	-597.81	0.0	-1882.66	2232.99	-2172.74	57
-739.03	-912.38	-621.41	0.0	-941.30	2434.98	-779.11	58
-54.73	-805.18	-700.07	0.0	1093.39	2065.31	1598.74	59
357.49	-695.21	-770.86	0.0	2537.17	1259.76	2688.35	60
-304.01	-722.38	-715.80	0.0	1461.20	468.55	187.56	61
-298.06	-747.78	-723.67	0.0	1675.98	324.42	230.88	62
-327.78	-670.87	-731.53	0.0	1463.46	274.58	7.82	63
234.17	-618.05	-794.46	0.0	2368.54	188.29	1378.50	64
-286.24	-681.14	-747.26	0.0	685.02	110.48	-919.14	65
-130.84	-670.48	-763.00	0.0	558.76	-17.38	-1022.93	66
-142.44	-660.51	-770.86	0.0	190.49	-174.87	-1558.19	67
-1443.95	-774.66	-1030.44	0.0	-2876.22	-354.48	-6479.75	68
-1840.24	-788.97	-1022.57	0.0	-3018.86	-351.78	-6689.10	69
-1764.61	-786.07	-1077.63	0.0	-3772.67	-370.72	-7741.71	70
-1818.18	-786.07	-1101.23	0.0	-3133.32	-378.83	-6884.62	71
-1813.76	-786.07	-1098.36	0.0	-3389.31	-376.13	-7198.65	72

J4. Ventilation Criteria.

HOURLY VENTILATION CRITERIA CALCULATED FOR THE MODEL HOG BARN

VENT.(IN)	VENT.M	RH.M	VENT.H	RH.H	SUPL.H	TOTAL	AN+H	T.O	T.I	WB.O	W	HR	RH.O
3000.	1303.	70.0	2938.	56.7	-11753.	21126.	24664.	51.7	58.6	44.8	15.2	1	59.2
3000.	1332.	70.0	2963.	57.0	-11918.	21649.	25000.	51.0	58.0	44.3	15.0	2	59.6
3000.	1193.	70.0	2940.	54.1	-13166.	22134.	25392.	50.1	57.3	42.9	14.9	3	56.3
3000.	1459.	70.0	2946.	58.5	-12513.	24790.	26633.	47.1	55.1	41.5	14.4	4	63.4
3000.	1288.	70.0	2968.	55.3	-13252.	23416.	26861.	47.2	54.7	40.7	14.3	5	56.0
3000.	1436.	70.0	2958.	57.8	-12358.	24008.	27319.	46.2	53.9	40.4	14.2	6	61.8
3000.	1472.	70.0	2969.	58.5	-11180.	22172.	26918.	47.5	54.6	41.5	14.3	7	61.3
3000.	1307.	70.0	2965.	56.2	-11982.	21421.	25729.	49.8	56.7	43.0	14.7	8	58.3
3000.	1250.	70.0	2968.	55.8	-13252.	22897.	24216.	52.0	59.4	45.1	15.4	9	59.4
3000.	811.	70.0	2955.	44.5	-13695.	18879.	21648.	57.8	64.0	46.7	16.7	10	43.3
3000.	715.	70.0	3055.	40.7	-15067.	19695.	19646.	61.2	67.8	48.5	18.0	11	39.8
3000.	603.	70.0	3024.	35.0	-13998.	17485.	17492.	65.4	71.1	49.7	19.5	12	31.8
3000.	623.	70.0	3085.	36.7	-13920.	17442.	16361.	67.3	72.9	51.7	20.4	13	34.0
3000.	686.	70.0	3020.	41.2	-12647.	16366.	14576.	70.2	75.6	55.3	21.9	14	39.1
3000.	674.	70.0	3010.	40.6	-12465.	15981.	14230.	70.8	76.1	55.5	22.3	15	38.2
3000.	694.	70.0	3049.	41.6	-12728.	16480.	14021.	71.0	76.4	56.1	22.4	16	39.8
3000.	747.	70.0	2959.	44.6	-10592.	14167.	13238.	72.7	77.5	58.1	23.1	17	42.1
3000.	746.	70.0	2938.	44.6	-10491.	14060.	13310.	72.6	77.4	58.0	23.0	18	42.1
3000.	774.	70.0	2963.	45.7	-10267.	13898.	13880.	71.9	76.6	57.8	22.5	19	43.3
3000.	1706.	70.0	3083.	63.1	-9344.	20927.	17615.	64.2	70.9	57.7	19.4	20	66.7
3000.	1992.	70.0	3069.	65.1	-7706.	21955.	20166.	59.6	66.6	54.2	17.6	21	71.8
3000.	2913.	70.0	2916.	70.0	-21.	21571.	21817.	56.5	63.7	52.5	16.6	22	77.7
3000.	4180.	70.0	2951.	73.0	9664.	23207.	23605.	52.9	60.5	50.0	15.7	23	82.6
3000.	3603.	70.0	2962.	72.3	6454.	22747.	24609.	51.3	58.7	48.2	15.2	24	80.9
3000.	3602.	70.0	2978.	71.8	4332.	20666.	24553.	52.1	58.8	48.5	15.2	25	76.3
3000.	3314.	70.0	2970.	71.1	2200.	19013.	23995.	53.6	59.8	49.5	15.5	26	76.8
3000.	3597.	70.0	2951.	71.9	4403.	20118.	24107.	53.0	59.6	49.3	15.4	27	76.1
3000.	3657.	70.0	2952.	72.0	5106.	21383.	24609.	51.7	58.7	48.3	15.2	28	79.3
3000.	4388.	70.0	2937.	73.5	10204.	20653.	24664.	51.8	58.6	48.6	15.2	29	80.5
3000.	3375.	70.0	2930.	71.4	3180.	20908.	24776.	51.5	58.4	47.9	15.1	30	78.1
3000.	3671.	70.0	2961.	72.1	5455.	22737.	25560.	49.6	57.0	46.5	14.8	31	80.4
3000.	3189.	70.0	2928.	70.9	1884.	21150.	24330.	52.2	59.2	48.5	15.3	32	77.8
3000.	2178.	70.0	2969.	66.4	-5504.	20667.	22378.	55.9	62.7	50.9	16.3	33	72.2
3000.	1626.	70.0	3066.	62.0	-9504.	20235.	20455.	59.6	66.1	53.1	17.4	34	66.8
3000.	1204.	70.0	3067.	56.4	-12216.	20114.	18882.	62.3	68.8	54.0	18.5	35	59.7
3000.	1137.	70.0	3035.	55.6	-10624.	17307.	16669.	66.4	72.1	56.9	20.0	36	57.0
3000.	1128.	70.0	3038.	55.6	-10079.	16003.	15384.	69.1	74.4	59.0	21.2	37	56.3
3000.	1032.	70.0	2997.	53.8	-9115.	13902.	13525.	72.4	77.1	60.9	22.8	38	53.0
3000.	969.	70.0	2910.	52.6	-7610.	11408.	11667.	75.6	79.6	62.7	24.5	39	50.8
3000.	893.	70.0	2962.	50.3	-8700.	12455.	11039.	76.1	80.4	62.5	25.1	40	48.0
3000.	876.	70.0	2936.	49.8	-7831.	11163.	10475.	77.2	81.1	63.0	25.7	41	46.8
3000.	989.	70.0	3002.	52.9	-9665.	14415.	12202.	74.0	78.9	62.0	24.0	42	52.2
3000.	1202.	70.0	3026.	57.2	-9892.	16407.	14437.	70.3	75.8	60.6	22.0	43	56.6
3000.	1352.	70.0	3014.	59.4	-9049.	16409.	16104.	67.8	73.3	59.1	20.6	44	61.2
3000.	2043.	70.0	3045.	65.6	-7642.	23231.	19937.	59.4	67.0	54.4	17.8	45	73.9
3000.	2120.	70.0	3028.	66.1	-5748.	19168.	20627.	59.5	65.8	53.9	17.3	46	70.9
3000.	2804.	70.0	2963.	69.8	-1063.	19771.	21592.	57.5	64.1	53.0	16.7	47	75.6
3000.	3935.	70.0	2955.	72.5	7600.	23525.	23661.	52.6	60.4	49.7	15.6	48	82.7
3000.	4259.	70.0	2958.	73.2	9709.	22082.	24385.	51.8	59.1	48.8	15.3	49	81.8
3000.	5058.	70.0	2946.	74.4	15133.	21106.	24609.	51.7	58.7	48.8	15.2	50	82.4
3600.	5011.	70.0	2940.	74.4	15513.	22016.	25167.	50.4	57.7	47.7	15.0	51	83.2
3000.	4937.	70.0	2912.	74.8	15181.	21824.	25448.	49.9	57.2	47.2	14.8	52	83.0
3000.	5640.	70.0	2943.	75.2	19375.	21142.	25392.	50.3	57.3	47.6	14.9	53	83.1
3000.	3856.	70.0	2953.	72.6	6883.	22487.	25897.	49.0	56.4	46.0	14.7	54	80.8
3000.	3209.	70.0	2973.	70.8	1771.	22342.	26123.	48.7	56.0	45.3	14.6	55	78.2
3000.	2436.	70.0	2922.	67.8	-3846.	23141.	26672.	49.1	56.6	45.2	14.8	56	75.3
3000.	2618.	70.0	2928.	68.7	-2410.	22827.	25088.	50.4	58.0	46.6	15.0	57	76.5
3000.	2316.	70.0	2953.	67.1	-5162.	23941.	24720.	50.6	58.5	46.6	15.1	58	75.4
3000.	1867.	70.0	2963.	63.8	-9881.	27215.	25616.	48.0	56.9	43.9	14.8	59	73.6
3000.	1556.	70.0	2932.	59.8	-14032.	29892.	27204.	44.3	54.1	39.9	14.2	60	69.5
3000.	2061.	70.0	2925.	65.1	-8195.	27736.	27849.	44.4	53.5	40.8	14.1	61	74.9
3000.	2279.	70.0	2947.	66.5	-6430.	26359.	28129.	43.3	52.5	40.1	13.9	62	77.1
3000.	2383.	70.0	2930.	67.2	-5340.	26605.	28597.	42.4	51.7	39.4	13.8	63	78.1
3000.	1840.	70.0	2949.	62.2	-11852.	31532.	30153.	39.0	49.1	35.5	13.4	64	78.8
3000.	2031.	70.0	2937.	64.1	-9131.	29602.	30821.	39.0	48.5	36.6	13.3	65	73.2
3000.	1981.	70.0	2943.	63.4	-9948.	30432.	31455.	37.3	47.0	33.9	13.1	66	78.1
3000.	1767.	70.0	2958.	60.3	-12801.	31051.	32609.	35.4	46.2	31.6	12.9	67	67.3
3000.	1261.	70.0	2931.	51.6	-23867.	41356.	47836.	33.3	46.4	29.3	13.1	68	62.8
3000.	1364.	70.0	2925.	54.2	-21858.	40956.	47645.	33.7	46.7	30.1	13.1	69	66.9
3000.	1226.	70.0	2929.	51.3	-25298.	43399.	51141.	33.8	47.5	29.9	13.2	70	64.3
3000.	1240.	70.0	2920.	51.9	-25360.	44069.	50954.	33.8	47.8	30.1	13.2	71	66.1
3000.	1270.	70.0	2925.	52.5	-24831.	43880.	51079.	33.7	47.6	30.1	13.2	72	64.9

APPENDIX K: COMPUTER TIME AND COST

NOTE: All times and costs are for a three-day simulation.

I. Compilation

Source Program	CPU Time (seconds)
MAIN	15.711
START	5.652
HPROD	1.065
PH2O	0.663
PICE	0.584
NAMEA1	18.981
POLES	4.188
MATRIX	4.996
ORIGIN	6.538
FREQRE	3.686
SOLVN	2.383
POLYM	0.992
AIRCAV	1.695
SOLAR	13.385
FLUX	4.184
WALL	2.330
VENTIL	2.130
TOTAL	89.163

Cost $4.46*

* Resource costs are based on the following formula:
Final cost = computer resource charge x priority factor x client factor
where CPU time = $300./hr
VM CPU = $3.00/page-hour
Priority factor = 1.3
Client factor = 0.6

APPENDIX K: Continued

II Execution

CPU Time = 84.802 seconds = $5.15

VM - CPU** = 219.304 Page minutes = $7.99

Total $13.14*

III Total Cost = $18.60 (including $1.00 for reading cards and printing).

** VM - CPU is the integral of vertual memory with respect to CPU time. It is the measure of the core storage reserved for the program.